The realized value of fiber infrastructure in Hamilton County, Tennessee

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Executive Summary

This study seeks to measure the realized value of fiber infrastructure in Hamilton County from 2011 to March 2015. Below, we summarize projections from Lobo (2011) relative to realized net benefits.

Realized Value of Fiber Infrastructure in Hamilton County				
Beneficiary	**Value Driver**	**Projected over 4 years** ($ million)	**Realized 2011-2015** ($ million)	
			Low	**High**
Households	Consumer Surplus	NA	$33.28	$76.29
	Customer Savings[1]	$86.70	$45.50	$45.50
	Online shopping[2]	$4.20	NA	NA
Community	New Investments	$457.52	$198.2	$461.02
	Taxes	$14.32	$25.76	$101.06
	Publicity	NA	$14.62	$24.37
	Venture Funds	NA	46.10	$53.60
	Telecommuting	$30.20	$10.99	$10.99
	Healthcare	$56.80	$9.02	$34.49
	Education	NA	$9.90	$9.90
	Civic Services	NA	NA	NA
Businesses	Business Efficiency & consumer surplus	$12.90	$234.19	$266.36
Utility	Smart Grid	$16.10	$237.72	$237.72
Total Net Economic & Social Benefits		$678.74	$865.36	$1,321.35
Per County Resident		$1,932.52	$2,463.89	$3,762.18
Total New Jobs		2,852	2,832	5,228
Realized-to-Projected: Net Economic & Social Benefits			127.5%	194.7%
Realized-to-Projected: Jobs			99.3%	179.9%

Lobo *et al* (2006) estimated that the Fiber-to-the-home/business (FTTH/FTTB) build-out would take ten years and generate benefits net of costs of $438 million in addition to about 2,600 new jobs. Lobo (2011) estimated the joint impact on Hamilton County of FTTH/FTTB and the Smart Grid to be about $1,196.2 million and 3,716 jobs. Of these, 3,595 were new jobs and 121 were avoided (hourly) job losses due to outage reduction benefits of a smart grid.

[1] In the 2011 study, these came from avoided rate hikes ($9.5m), triple-play cost savings ($4.9m) and projected DSM programs ($72.2m). In the current study, realized DSM programs have been counted with Smart Grid benefits.

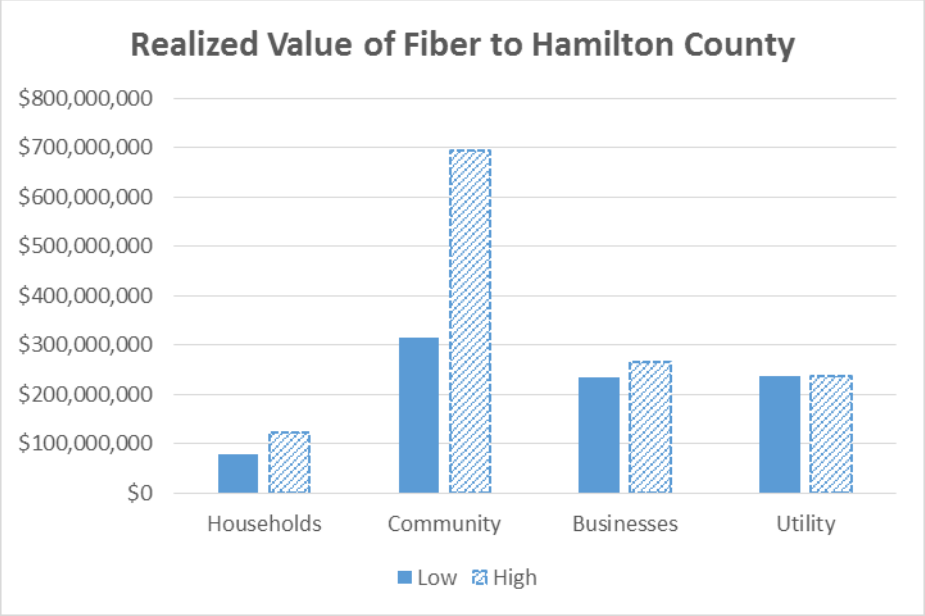
[2] Incorporated in consumer surplus in the current study.

The net benefits cited in the 2011 study stemmed from $589.8 million in added income and taxes, and from indirect social benefits. The latter were estimated to be $209.3 million annually. It was assumed that these benefits would accrue to the community at the rate of 10% in the first year, 20% in the second, 30% in the third, 40% in the fourth, 50% in the fifth year and 60% thereafter indefinitely. When scaled to a four-year (comparison) period, the social benefits amount to $207.86 million, while the cumulative economic and social benefits amount to $678.74 million and 2,973 jobs. This translates to a benefit of $1,932.52 per county resident.

We find that over the period 2011-2015, the fiber infrastructure has generated incremental economic and social benefits ranging from $865.3 million to $1.3 billion while additionally creating between 2,800 and 5,200 new jobs. We find that the realized benefits have exceeded the projected benefits by at least 27 percent and, possibly, by as much as 95 percent. These estimates translate to benefits of between $2,832 and $3,762 per county resident. Moreover, between 100 percent and 180 percent of the projected job creation has been realized in Hamilton County over this four-year period.

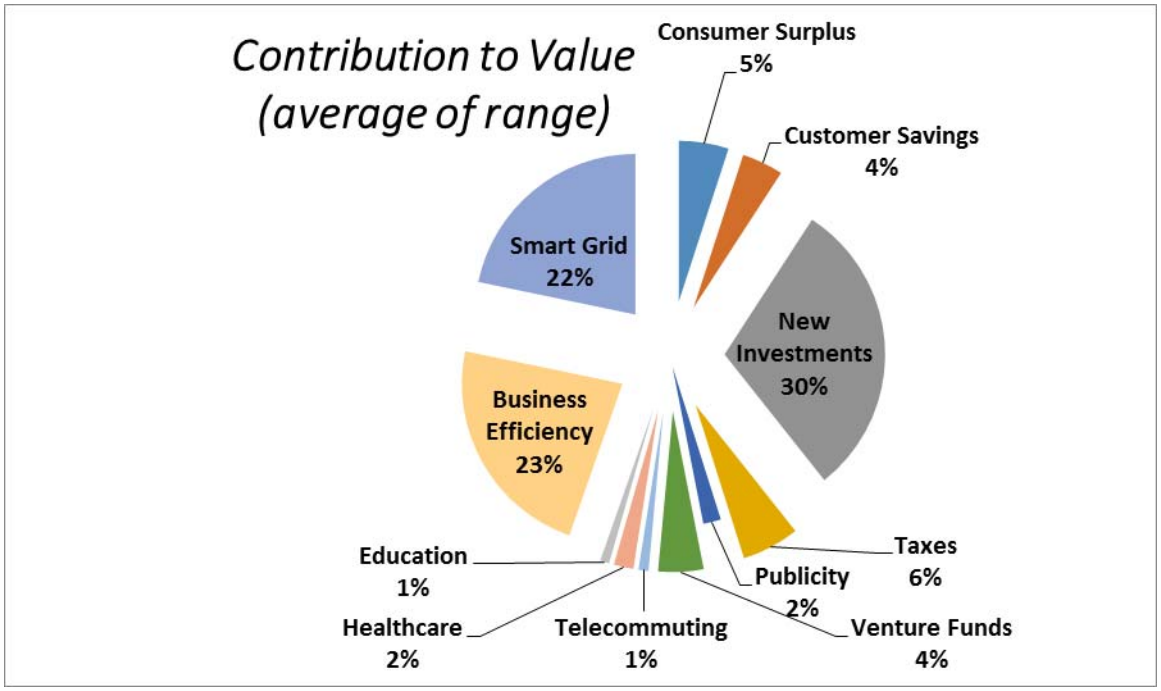
When we consider that both the broadband and the smart grid infrastructure were built out ahead of schedule, the fiber investment in Hamilton County appears set to deliver benefits at a faster pace than previously predicted. In particular, our estimates suggest that the Smart Grid has already generated benefits in excess of its construction cost of $163.3 million (Lobo, 2009).

The impact of high-speed broadband was analyzed in four categories: household, community, business and utility effects. The categories are not mutually exclusive as explained in the methodology, but were used as a way to organize the findings. The value beneficiaries of the fiber infrastructure are summarized in the chart below.



Our calculations suggest that the community benefits the most (46%), followed by businesses (23%), the utility (22%) and households (9%). About 75% of the recorded gains to the County have come from new investments, business efficiencies and from the many benefits of the smart grid. Relative to the predictions found in the literature, telecommuting, healthcare, education and civic services have lagged in generating significant benefits to the community.

The value drivers are summarized below.



This study suggests that the true economic value of the fiber infrastructure is much greater than the cost of installing and maintaining the infrastructure. As measurement methods improve, new pockets of value will likely be discovered which will add to the estimates provided in this study.

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INTRODUCTION

Background

In 2005, EPB planned to build out a new fiber optic infrastructure in the community to modernize the electric system and provide fiber-to-the-home (FTTH) and fiber-to-the-business (FTTB) telephone/internet/TV service to residential and commercial customers. In September 2007, Chattanooga's City Council approved EPB's FTTH plan. The build out was completed roughly 6 years ahead of schedule and the first customers were connected in the fall of 2009. In September 2010, EPB made available residential symmetrical internet connection speeds of up to one gigabit per second - the fastest Internet in the western hemisphere. By 2010, the utility saw a 150 percent increase in customers. As of March 2015, the utility serves 43 percent of the Chattanooga residential market, a total of roughly 66,180 customers. Moreover, the fiber optic division of EPB became profitable in 2012 and has contributed to lowering EPB's overall operating costs and electric rates ever since. By 2016, the division is expected to be debt-free.[3] Fiber optic system access fees and rents paid to the electric system in 2014 amounted to $10 million and are estimated to be over $12 million in fiscal 2015.

In 2008, plans to modernize the electric system took off with EPB making a bond offering to fund the construction of a Smart Grid, one of the first and largest in the United States. In November 2009, in the wake of the deep recession of 2007-2008, EPB received a federal stimulus matching grant in the amount of $111.6 million from the Department of Energy to expedite the build-out and implementation of the fiber infrastructure and Smart Grid.[4] The fiber optic division was set up as an asset of the electric division of the utility and leases the fiber optic infrastructure from the electric division.

In 2010, *Business Facilities Magazine* ranked Chattanooga #1 among all American metros for "Economic Growth Potential".[5] Chattanooga had begun to attract bandwidth-hungry businesses. *HomeServe* hired 140 employees to launch a call center in the city. The company cited Chattanooga's speedy Internet as "one of the reasons" the company decided to open its data-intensive facility here. In the meanwhile, a RelocateAmerica.com study indicated that the city was attracting people at a rate about 30 percent faster than the national average, especially baby boomers and members of the millennial generation, i.e. a group characterized as the young, creative class - the driving force behind new, innovative businesses.[6]

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[3] http://www.timesfreepress.com/news/local/story/2015/may/23/epb-proposes-35-percent-rate-increase-july/305911/

[4] http://www.epb.net/about/our-company-and-history/ This grant was matched $111.5 million in cash by EPB and the City of Chattanooga, and $3.57 million by EPB's private partners, Alcatel-Lucent, Tantalus, and Medium.

[5] http://www.businessfacilities.com/Rankings/BFJulAug10_METRO_RANKINGS.PDF

[6] http://www.timesfreepress.com/news/2008/may/17/chattanooga-ranked-third-best-place-live/

In January 2011, Chattanooga was named one of seven finalists globally vying for the title of "2011 Intelligent Community of the Year" by the Intelligent Community Forum (ICF). ICF seeks to share the best practices of the world's Intelligent Communities in adapting to the demands of the Broadband Economy, in order to help communities everywhere find sustainable renewal growth. Past winners of the "Top Intelligent Community" honor included Seoul (South Korea), Stockholm (Sweden), Taipei (Taiwan) and New York City (U.S.). According to ICF,

> *"The Top Seven represent models of economic and social transformation in the 21st Century. They are not the most advanced technology centers, the most wired cities or the fastest growing economies in the world. Instead, each exemplifies best practices in broadband deployment and use, workforce development, innovation, digital inclusion and advocacy that offer lessons to regions, cities, towns and villages around the world. They are charting new paths to lasting prosperity for their citizens, businesses and institutions."*[7]

Since 2010, the "Gig City" has started to garner global awareness and media coverage. A sampling of media sources and articles is listed below:

The Guardian – How One City's Super-Fast Internet is Driving a Tech Boom
New York Times – Fast Internet is Chattanooga's New Locomotive
CBS Morning News – Which City has the Fastest Internet in the Nation?
Al Jazeera English – New Technology to Protect US Grid
Thomas Friedman column in the New York Times - Obama's Moment
CNBC – Rebooting Chattanooga's Fortunes
Atlanta Journal Constitution – Technology Thriving
Wired – Where High Speed Internet Meets Smart Grid
Fast Company – A Small City with a Smarter Grid
GreenTech Media – Top 10 Utility Smart Grid Deployments in North America
The Economist – The need for speed
Wall Street Journal – Cities start own efforts to speed up Broadband
Wall Street Journal – Getting "Smart" on Outages
Forbes – The New Metropolis: The New Urban Pioneers

This high quality exposure helps draw the attention of vibrant and innovative workers and entrepreneurial talent. It also draws business investment to the area. The advertising-equivalency value for this media exposure is calculated in the next section.

Previous Estimates

A 2006 study (Lobo *et al,* 2006) examined for the first time the IMPLAN-generated output/employment/tax impacts of EPB building out a FTTH/FTTB network. The underlying premise of the study was that the entire investment would be made in the telecommunications sector to support a FTTH broadband network with only limited implications for the electric division of the utility. This was a pioneering study in that it was a first attempt at assessing the direct/indirect/induced effects of such an investment on the regional economy. Moreover, the study provided analytical estimates of the social

[7] https://www.intelligentcommunity.org/index.php?submenu=Awards&src=gendocs&ref=Top7&category=Events&link=Top7

effects of the project on Hamilton County, Tennessee. A portion of this study was published in the *Journal of Applied Business Research* (Lobo, Ghosh and Novobilski, 2008) and was subsequently cited in a study conducted by the World Bank.[8]

The study was based on capital expenditures of $195.5 million spread over a ten-year period. Assumptions were made in estimating the incremental social effects in the areas of telemedicine, telecommuting, e-business, e-entertainment and e-government. The incremental economic and social benefits of the project were estimated to be approximately $438 million, in addition to about 2,600 new jobs. The study concluded that "like good roads, schools, and hospitals, cutting-edge broadband infrastructure was crucial to economic development and to the quality of life of the community."

A subsequent study (Lobo *et al*, 2009) examined the economic impact of an investment of $163.3 million in a Smart Grid project for the EPB footprint. The underlying assumption was that the investment would be an electric division investment in smart grid infrastructure and that some baseline demand-side management (DSM) assumption would be in effect. The study was conducted independently of the 2006 study. The authors found that the project could generate over $266 million in incremental value while creating in excess of 2,100 new jobs in Hamilton County. Much of this value stemmed from customer bill savings from demand-side management, benefits to the Tennessee Valley Authority (TVA) from not having to build costly additional capacity, environmental and health benefits and the provision of more efficient electric utility services.

Lobo (2011) examined the joint impact on Hamilton County of FTTH/FTTB and the Smart Grid in measuring the overall value to the community of this fiber infrastructure. The study generated IMPLAN estimates of income, tax and employment effects based on an assumed 5-year expenditure pattern. The study estimated that the net economic and social value to Hamilton County of the integrated capital expenditures of $396.1 million on fiber optic infrastructure to support FTTH/FTTB broadband and a Smart Grid was roughly equal to $1.196 billion and about 3,716 new jobs. Of this, $589.8 million would accrue from added income and taxes and about $1 billion would accrue gradually from additional social and indirect benefits. These annual social benefits of $209.3 million, were assumed to accrue "at the rate of 10% in the first year, 20% in the second, 30% in the third, 40% in the fourth, 50% in the fifth year and 60% thereafter indefinitely." The present value of this stream of benefits at a 10% discount rate was estimated to be just over a billion dollars. Thus, over a four-year period, the social benefits would amount cumulatively to $207.8 million. Over the same length of time, the cumulative economic and social benefits would be projected to amount to $678.7 million and 2,973 new jobs. The net benefit to each county resident would translate to $1,932.52.

[8] http://siteresources.worldbank.org/AFRICAEXT/Resources/258643-1271798012256/YAC_chpt_19.pdf

Scope of this study

This study seeks to compare the estimates from Lobo (2011) to the realized economic value in Hamilton county, and Chattanooga in particular. The study examines mostly a 4-year period from 2011 to March 2015. The study examines the amount of business investment and number of firms that have moved to Chattanooga, and the number of jobs that have been created as a consequence. The study examines the effects of the fiber infrastructure on customers, businesses, the electric utility and the community at large.

For the purposes of this study, we distinguish between broadband and high-speed broadband. Broadband refers to the bandwidth used to transmit data signals across the internet. Greater bandwidth permits a larger volume of information to be transmitted at greater speed. The use of the term "broadband" will generally refer to the new FCC benchmark of Internet download speed of 25 megabits per second or faster and upload speed of 3 Mbps or faster. In this study, "high-speed broadband" will refer to symmetric download and upload speeds of 100 Mbps or greater.

Quick Facts

Table 1. Hamilton County and Chattanooga Demographic Profile			
	Hamilton county	**City of Chattanooga**	**Source**
Population (2013)	351,220	173,366	Census[9]
Households (2009-2013)	135,496	70,139	Census
Household size (2009-2013)	2.45	2.33	Census
Population above 5 years of age (2010)	94.1%	93.6	Census
Median household income (2009-2013)	$46,702	$38,064	Census
Median hourly earnings	NA	$19.25	BLS[10]
Median value of owner-occupied housing (2009-2013)	$154,200	$138,100	Census
Total # of firms (2015)	21,792	28,507	Chamber[11]
Private nonfarm employment (2015)	213,768	261,219	Chamber
Mean travel time to work (minutes) (2009-2013)	21.5	18.5	Census
Labor force	163,260	248,550	Tn.gov[12]

[9] http://quickfacts.census.gov/qfd/states/47/4714000.html; and http://www.chattanoogachamber.com/media/population.pdf
[10] As of May 2014: http://www.bls.gov/regions/southeast/news-release/occupationalemploymentandwages_chattanooga.htm
[11] http://www.chattanoogachamber.com/media/businessdemo-1.pdf; For the MSA not the city.
[12] http://www.tn.gov/labor-wfd/labor_figures/LaborJAN2015.pdf

Fiber customers in Hamilton County

Table 2. Fiber Customer Profile

Residential fiber users in Hamilton County*

Service	2010	2011	2012	2013	2014	2015ǂ
Data only	1,606	3,085	4,725	7,145	10,227	11,531
Phone only	302	552	729	887	866	880
Video only	2,281	3,108	3,722	3,996	4,170	4,108
Data & Phone	889	1,538	1,769	2,124	2,215	2,288
Data & Video	5,809	9,764	13,333	17,605	22,103	23,052
Phone & Video	1,206	1,793	2,209	2,588	2,864	2,858
Tri-Fi Bundle	9,222	14,444	16,535	19,010	21,101	21,463
Total	**21,315**	**34,284**	**43,022**	**53,355**	**63,546**	**66,180**
Total Data	**17,526**	**28,831**	**36,362**	**45,884**	**55,646**	**58,334**

Commercial fiber users in Hamilton County*

Service	2010	2011	2012	2013	2014	2015ǂ
Data only	NA	303	529	843	829	874
Phone only	NA	141	238	308	424	461
Video only	NA	44	57	70	79	92
Data & Phone	NA	838	1,267	1,790	2,369	2,435
Data & Video	NA	63	123	211	151	170
Phone & Video	NA	30	47	45	67	70
Tri-Fi Bundle	NA	463	709	902	1,242	1,295
Legacy Only	NA	0	0	428	298	239
Total	NA	**3,893**	**4,982**	**6,610**	**7,473**	**7,651**
Total Data	NA	**1,667**	**2,628**	**3,746**	**4,591**	**4,774**
Residential + Commercial Total	21,315	38,177	48,004	59,965	71,019	73,831
Residential + Commercial Data Total	17,526	30,498	38,990	49,630	60,237	63,108
Residential + Commercial Data Take rate	10.2%	17.7%	22.6%	28.6%	34.3%	35.9%
Residential Data Take rate	14.2%	22.7%	28.4%	35.0%	41.1%	42.8%

Source: EPB. Data presented for Jan-Dec of each year.
* Over 90% of the EPB footprint is made up of Hamilton County (TN). ǂ Through March 31.

Additional observations:

- The residential take rate for data is about 43%; the joint residential and commercial take rate is about 36%
- 89.64% of all broadband customers are residential
- 9.16% of residential customers who take the data service subscribe to the Gig (5,341)
- 0.73% of commercial customers who take the data service subscribe to the Gig (35)
- 41.67% of commercial customers who take the VLAN service subscribe to the Gig (40 out of 96)

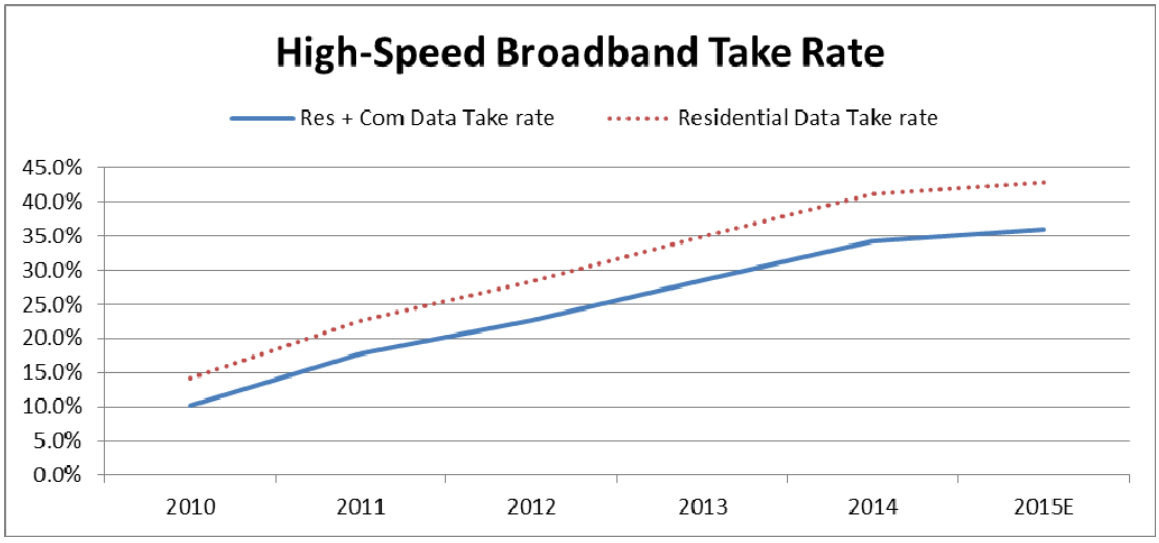

Figure 1. Broadband Take Rates

At the time of this report, EPB Fiber optics is the only provider of fiber services in Hamilton County and Chattanooga.

METHODOLOGY

This study is focused on capturing the realized economic value of the fiber infrastructure. In particular, our approach seeks to measure *only the incremental effects* of high-speed broadband and a smart grid.[13,14] This means that any measured effects must adjust for the counterfactual case of having an alternative infrastructure in place, i.e. broadband, as opposed to high-speed broadband, and a traditional instead of a smart electric grid.

The analysis is challenging partially because of a lack of data at the local level, and sometimes even at the national level. We identify at various points in the study the types of data that need to be collected going forward so as to enable a more detailed quantification of the effects of this infrastructure in the future. By way of illustrations, and sometimes for added emphasis, we selectively use anecdotal evidence from case studies developed for this analysis as well as from *Smart Chattanoogans: Stories of a Fiber Optic Community – Volume 1*.[15]

While every effort has been made to be as systematic as possible in capturing the effects of the fiber infrastructure, such an endeavor has an element of *ad hoc-ism* associated with it. This is because no holistic theory exists to capture the impact of broadband access to the internet. Consequently, the empiricist must approach the problem in the most reasonable but practical way. An additional complication is that people do not generally consider counterfactuals when assigning benefits and costs to different products and services – a requirement of this study. Consequently, our approach has been to examine areas indicated in Lobo (2011) and references therein, that are most likely to be impacted by the fiber infrastructure, such as healthcare, education and business productivity, and to develop metrics appropriate for those sectors/areas with available data.

The development of metrics is challenging. How do you measure the value of an evolving entrepreneurial ecosystem? Are firms attracted to this area because of particular features of the infrastructure? Consequently, how do we attribute investments and jobs to particular features of a location when such answers are not elicited from relocating firms? Has shopping behavior changed because we now shop online? How do you measure the satisfaction of learning something instantly on the internet? Productivity gains are particularly hard to measure. What is the dollar value of a teacher who has more time to

[13] Greenstein and McDevitt (2010) argue that the much-cited Crandall and Jackson (2003) is flawed in failing to consider the counterfactual gains from continuing with dial-up internet access. Lobo et al (2006) make this adjustment.

[14] Measuring the value of a good is much trickier than measuring the cost, since value inherently involves consideration of a hypothetical: what would your life be like without that good? Economists commonly use two measures to assign monetary value to some good or service: the "compensating variation" and the "equivalent variation". The compensating variation asks how much money we would have to *give* a person to make up for taking the good away from them while the equivalent variation asks how much money someone would *give up* to acquire the good in question. The term "consumer surplus" refers to an approximation to these theoretically ideal measures.

[15] EPB Case Studies: 30 June 2011. Print.

engage with students because she doesn't have to spend excessive amount of time uploading and downloading files and dealing with a slow internet connection? How much time and money is saved from enhanced business productivity? This is a particularly hard question to answer when businesses consider such information to be proprietary.

In many cases, we have identified benefits in the form of cost savings or time savings. In the latter case, a median hourly wage rate is often applied. Often cost savings to residential and/or commercial customers stem from EPB offering services at a cheaper price than the competition. How is this possible? The answer lies in the fact that EPB is a not-for-profit entity that is completely vested in the local community. The value proposition centers on societal benefits which may not easily translate into monetary benefits. Private Cable and Satellite providers offer services subject to profitability constraints. In relatively smaller markets such as Chattanooga, this results in higher prices relative to EPB.

Depending on data availability, our analysis covers either a three-year or four-year period from either 2012 or 2011 to March 2015. The exception is the analysis of new investments and jobs, which we track from 2009 because by this time the imminent availability of FTTH/FTTB in the area was well known and would have factored into business location decisions. Moreover, the first fiber customers were signed up in the fall of 2009. Consequently, we compare the realized net benefits in this study to a four-year projection of net benefits from the Lobo (2011) study.

We have also applied the notion of consumer surplus as discussed in the "Household Effects" section to capture non-monetary benefits of convenience and reliable connectivity that comes from high-speed internet access. Future research will be in a better position to clarify some of these effects and possibly offer a more complete picture.

In the analysis to follow, the effects of high-speed broadband have been analyzed in four categories: household effects, community effects, business effects and utility effects. This is one of many classifications possible. The categories are not necessarily mutually exclusive, but are merely an attempt at organizing the analysis. In particular, household effects are those that can be attributed to bill savings of individual households. Community effects, by contrast, accrue to the community-at-large but cannot be directly linked to individual household bills. Business effects, however, overlap community effects since benefits to local businesses benefit the local economic landscape. Importantly, utility effects strongly overlap community effects because the utility is city-owned. For instance, the benefits stemming from the smart grid are attributed to the Utility. However, since the utility is city-owned, such benefits effectively accrue to the community that the utility serves. In particular, the benefits from stemming the costs of major weather events accrue mostly to businesses and households in terms of a reduction in lost productivity and economic activity. However, we include these benefits in the "Utility Effects" section of the paper because they are attributable to the smart grid infrastructure.

Household Effects

Consumer Surplus

Traditionally, the economic effects of infrastructure projects such as internet access have been measured in one of two ways: 1) with an IMPLAN-type model; 2) and via analytical techniques. In this study, the issues pertain to distilling the incremental effect of high-speed broadband and the smart grid relative to a world without those technologies or with different technologies. Measured effects must be careful to separate confounding factors from those that are directly attributable to the technology/infrastructure being studied. Greenstein and McDevitt (2009) argue that early studies of the value of broadband were overestimated because the "incremental" element of the new service was not considered.[16]

Following Lobo (2011), our approach to measuring the value of the fiber infrastructure is primarily based on the idea that high-speed broadband is infrastructure similar to good roads and bridges. In 2010, then Prime Minister of Australia, Julia Gillard, said: *"Just as railway networks drove an economic transformation in the 19th century, and electricity networks in the 20th century, so high-speed broadband will transform economies in decades to come."*

As a reference point, we consider work done in measuring the economic impact of the internet. The measurement is difficult because so much of the impact of the internet has no price, i.e. has non-monetary benefits. This is an old problem in economics. GDP, for instance, measures monetary transactions, not welfare. "Consider someone who would pay $50 for the latest Harry Potter novel but only has to pay $20. The $30 difference represents a non-monetary benefit called "consumer surplus". The amount of internet activity that actually shows up in GDP significantly understates its contribution to welfare by excluding the consumer surplus that accrues to users."[17] After making methodological adjustments, Greenstein and McDevitt estimated that by 2006 broadband (not, high-speed broadband) was generating $39 billion in revenue and $5 billion-$7 billion in consumer surplus in the U.S. each year.

We use household consumer surplus as a proxy for the additional non-monetary benefits of high-speed internet access. In particular, we use it as a gauge of hard-to-measure benefits from "always on" service with few outages or buffering issues such as the convenience of shopping from home or reading an e-book or viewing a streaming video or gaming.

Measuring consumer surplus

An approach to estimating consumer surplus is simply to ask consumers what they would pay if they had to. In a study commissioned by IAB Europe, a web-advertising industry group, McKinsey, a consultancy, asked 3,360 consumers in six countries what they would pay for 16 internet services that were largely financed by ads. On average,

[16]http://www.kellogg.northwestern.edu/faculty/greenstein/images/htm/Research/WP/Broadband%20Bonus%20-%20GreensteinMcDevitt-4.pdf

[17] http://www.economist.com/news/finance-and-economics/21573091-how-quantify-gains-internet-has-brought-consumers-net-benefits

households would pay €38 ($50) a month for services they got for free. After subtracting the costs associated with intrusive ads and forgone privacy, McKinsey estimated free ad-supported internet services generated €32 billion of consumer surplus in America and €69 billion in Europe. E-mail accounted for 16% of the total surplus across America and Europe, search 15% and social networks 11%.

Rosston, Savage and Waldman (2010) show that reliability and speed are important characteristics of Internet service. The representative household is willing to pay about $20 per month for more reliable service and $45-48 for an increase in speed. Willingness-to-pay (WTP) for speed increases with education, income and online experience, and decreases with age. Rural households value connection speed by about $3 more per month than urban households. Households are also willing to pay an additional $6 so that their Internet service provides the ability to designate downloads as high-priority, about $4 for the ability to interact with health specialists online, about $3 for the ability to download and view full-length movies, and about $5 for the ability to place free phone calls over the Internet and see the person being called.

Using these results, they calculate that a representative household would be willing to pay about $59 per month for a less reliable Internet service with fast speed ("Basic"), about $85 for a reliable Internet service with fast speed and the priority feature ("Premium"), and about $98 for a reliable Internet service with fast speed plus all other activities ("Premium Plus"). An improvement to very fast service adds about $3 per month to these estimates.

Another way to infer consumer surplus is from the time saved using the internet. In a paper partly funded by Google, Chen, Jeon and Kim (2014) found that on average, it took participants seven minutes to answer some survey questions using a search engine, and 22 minutes using the University of Michigan's library. Hal Varian, Google's chief economist, then calculated that those savings worked out to 3.75 minutes per day for the typical user. Assigning that time a value of $22 per hour (the average wage in America), he estimated search generates $1.37 of consumer surplus per day per user, $500 annually, or $65 billion-$150 billion nationally.

Yet another way to measure consumer surplus is to assign a value to the leisure time spent on the web. Erik Brynjolfsson and Joo Hee Oh of the Massachusetts Institute of Technology note that between 2002 and 2011, the amount of leisure time Americans spent on the internet rose from 3 to 5.8 hours per week. The authors conclude that in so far as consumers must have valued their time on the internet more than the alternatives, this increase must reflect a growing consumer surplus from the internet, which they value at $564 billion in 2011, or $2,600 per user. Had this growth in surplus been included in GDP, it would have raised economic growth since 2002 by 0.39 percentage points on average.[18]

What Can You Do With Speed?

[18] http://conference.nber.org/confer/2012/EoDs12/summary.html.

A much-touted benefit of high-speed broadband is that it enables the more convenient conduct of ordinary activities including shopping, banking and entertainment. Consequently, Orszag, Dutz and Willig (2009) found that the benefits of an increase in broadband speed from 100 times the typical historical speed of dial-up Internet service to 1,000 times dial-up are on the order of $6 billion per year for existing home broadband users. [19]

Table 3. What Can You Do With Speed?

		Download Time (seconds)		
File Size	**Activity**	**25 Mbps**	**50 Mbps**	**150 Mbps**
2.5 MB	Short video clip	1.3	0.4	0.1
50 MB	10 songs	26.7	8	2.7
100 MB	20 high-resolution photographs	53.4	16	5.4
250 MB	20-minute SD video	132	40	13.3
1.5 GB	2-hour SD video	798	240	78

Source: *"Verizon FiOS Speeds." Available at* http://fios.verizon.com/fios-speeds.html

Broadband is not only much faster than dial-up, but it is typically provided in a way that is "always on." The combination of speed and availability makes home broadband connectivity an extraordinarily powerful and flexible tool that is already widely used for entertainment, work and job searches, news, health care, shopping, personal finances, social networking, travel, education and interactions with government. The economic and social transformations to households and business users from faster broadband speeds and more ubiquitous broadband connections are just beginning. The Pew Research Center's Internet & American Life Project (May 2013) reported that 70% of American adults ages 18 and older have a high-speed broadband connection at home.[20]

The American Time Use Survey (2009) indicated that the average adult spends about 30 minutes per day for non-grocery shopping and 15 minutes traveling for such shopping.[21] The time a person spends shopping is an important economic cost. According to a global survey conducted by The Nielsen Company, over 85 percent of the world's online population has used the Internet to make a purchase, and more than half of Internet users are regular online shoppers, making online purchases at least once a month.[22]

Internet banking, along with location-based services and time-shifted TV viewing, is among the top three fastest growing trends in online activities.[23] Moreover, Statista

[19] http://www.internetinnovation.org/library/consumer_benefits_broadband_study/
[20] http://www.pewinternet.org/2013/08/26/home-broadband-2013/
[21] Source: See The BLS's *American Time Use Survey 2009* http://www.bls.gov/tus/#tables
[22] http://id.nielsen.com/news/documents/GlobalOnlineShoppingReportFeb08.pdf
[23] http://www.go-gulf.com/blog/online-time/

(2013) reports that the daily time spent playing video games per capita in the U.S has grown to 23 minutes in 2013, up from 18 minutes in 2008.[24]

CASE STUDY:[25] The Shults Family

Tim Shults, his wife Berry, and their two children are wired to the Internet in some capacity at least seven hours a day.

> *"My wife and I use the connection for work, but we also use broadband heavily in our day to day lives. We can have two movies streaming from Netflix while listening to streaming music from Pandora with both my wife and I working online with no problems whatsoever. You can't find that anywhere else," says Tim of his fiber optic service.*

After launching his business, LoKewl, at the 2009 48-Hour Launch, Tim continues to utilize the broadband service from his home.

> *"It's allowed my business to flourish," says Tim. "With the reliable bandwidth, I have been able to take on freelance development work and have the freedom to work odd hours. The consistency and speed of this network has contributed to my ability to follow my passion professionally while giving me the opportunity to spend more time with my family. There are other providers here, but you can't even compare the service."*

Berry Shults took advantage of the 1 gigabit connection EPB supplied to the 2011 48 Hour Launch and the volunteer technical expertise to spark her business' web presence. Her concept, Relove to Reduce, an online consignment shop promoting waste reduction, launched a significant online presence in just a couple of days. Berry's business partner, Kacee Nazor, commented "We have gotten more done in five hours than we have in the past five months!"

Berry, a part time teacher at the local environmental charter school, uses the fiber connection to download lesson plans and grade student papers remotely. The Shults children also use the connection to enhance their education, downloading online quizzes, learning games, and materials to assist with homework – all while their parents run bandwidth-heavy applications.

Data limitations

A measure of some of the value of high-speed broadband in Hamilton County would be possible if data on the extent of online shopping and banking were readily available. In such case, a measure of consumer value would be the time savings and travel cost savings from not having to shop or bank face-to-face, but also in terms of the gains from leisure from such time savings. More refined bandwidth usage data by zipcode would allow for

[24] http://www.statista.com/statistics/186960/time-spent-with-videogames-in-the-us-since-2002/
[25] EPB Case Studies: 30 June 2011. Print.

more granular examination of digital divides. Absent such granular data, we proxy the local effects based on consumer surplus estimates.

Going forward, it would be interesting to learn of consumer WTP for high speed broadband in the region using survey methods or laboratory experiments. Without such estimates, we use findings of WTP from other studies to guide our analysis.

Residential Consumer Surplus in Hamilton County

To calculate the consumer surplus of the FTTH in Hamilton County, we use two approaches:

1. Willingness-to-pay: Rosston *et al*, 2010
2. Time savings from search: Varian, 2014

Approach 1: Willingness-to-pay

Here we use estimates from Rosston *et al*, who find that a representative household would be willing to pay $98 per month for a reliable Internet service with fast speed plus all other activities ("Premium Plus"). Moreover, such a household would pay an additional $3 per month for very fast service (for which 100 Mbps or higher would qualify). The consumer surplus would be measured relative to the current price for high speed broadband in Hamilton County. Since EPB offers two service levels, 100 Mbps and 1000 Mbps, at $57.99 and $69.99, we use a weighted average of the two service prices, i.e. $59.09. The monthly consumer surplus is $41.91 times the number of households taking EPB's high-speed broadband.

As an additional check on this approach, we approximate consumer WTP by using competitor pricing in the area. Comcast's weighted average highest-speed rate is $102.00 for the XFINITY Internet Extreme 105 Package (download speeds up to 105 Mbps).[26] The monthly consumer surplus is $42.91 per household taking EPB's high-speed broadband, very similar to estimates from Rosston *et al*.

Approach 2: Time savings from search

The second approach is based on Varian's measure of time saved from using the internet. He estimated that the savings amounted to $1.37 *per user* per day or $500.05 per user per year.

We proxy for the number of users with the number of households taking high-speed broadband in Hamilton County as of March 31, 2015. The number of households is then adjusted for the average size of the household as suggested by the Census Bureau after controlling for children 5 years old or younger.

The consumer surplus estimates are presented in the table below.

[26] Note that, at the time of writing, this is the only provider other than EPB that offers any internet service greater than 100 Mbps.

Table 4. Consumer Surplus in Hamilton County			
Approach	**Consumer Surplus per month**	**Users = Households x size**	**Annual Consumer Surplus**
WTP	$101 - $59.09 = $41.91	66,180	$33,284,272
Time savings	$500.05/12 = $41.67	66,180 x 2.45 x 94.1%[27]	$76,294,969

Our estimates suggest that consumer surplus related to high-speed internet access ranges from $33.2 million to $76.2 million annually. As previously mentioned, we use this surplus as a proxy for incremental non-monetary benefits experienced by residential customers from high speed internet access.

[27] Adjusted for children 5 years old and younger (5.9%).

CUSTOMER SAVINGS

Lower Power Bills

The fiber optics division at EPB has helped reduce O&M costs while also generating access fee revenues for the electric division as seen in the table below. The Broadband division began to turn a profit as soon as 2012, and by 2014, was generating $9.9 million in profit, $14.2 million in O&M cost reduction and $11.9 million in access fee revenue for the electric division.

Table 5. EPB Fiber Optics Division Contribution to Electric System

	2010	2011	2012	2013	2014	2015E
Net income	(5,908)	(1,835)	4,086	5,550	11,401	9,927
O&M reduction	2,112	5,639	7,635	9,742	10,350	14,249
access fees	604	4,411	7,594	7,924	9,739	11,865

Source: EPB. Figures in '000s.

The result has been lower power costs for customers and deferment of any rate hikes at least for one year. In fact, EPB customers have paid an average of 15.3% less for power than the national average from 2012-2014.

EPB's 2014 Annual Report points out that despite the rising cost of and demand for energy, EPB was able to avoid a 4-5% rate hike in 2013-2014. To calculate the annual savings to residential customers of this avoided rate hike, note that the average residential electric bill was $124.25 according to the EIA.[28] A 4.5% avoided rate hike would save customers the following:

4.50% x average bill x 12 months x # residential customers or meters

For a total of 153,879 residential customers, the savings amounts to $10,324,512. However, customers benefited in this amount for two years through to the time of this writing. Consequently, the realized benefit of the avoided rate hike is $20,649,023.

Competition Brings Lower Prices

Additionally, the Lobo *et al* (2006) and Lobo (2011) studies estimated cost savings associated with additional competitive pressures in the telephone/internet/TV services offerings in the county. The research question was: *How much less will residents pay for internet service in the face of competition?* Triple Play prices were anticipated to drop by 20% due to competitive pressures. In particular, the benefit stemming from added competition was estimated to be about $15 per month per subscriber. The chart below shows the drop in internet (data) service costs in Hamilton County from 2011 to 2014.

[28] http://www.eia.gov/energyexplained/index.cfm?page=electricity_home#tab2

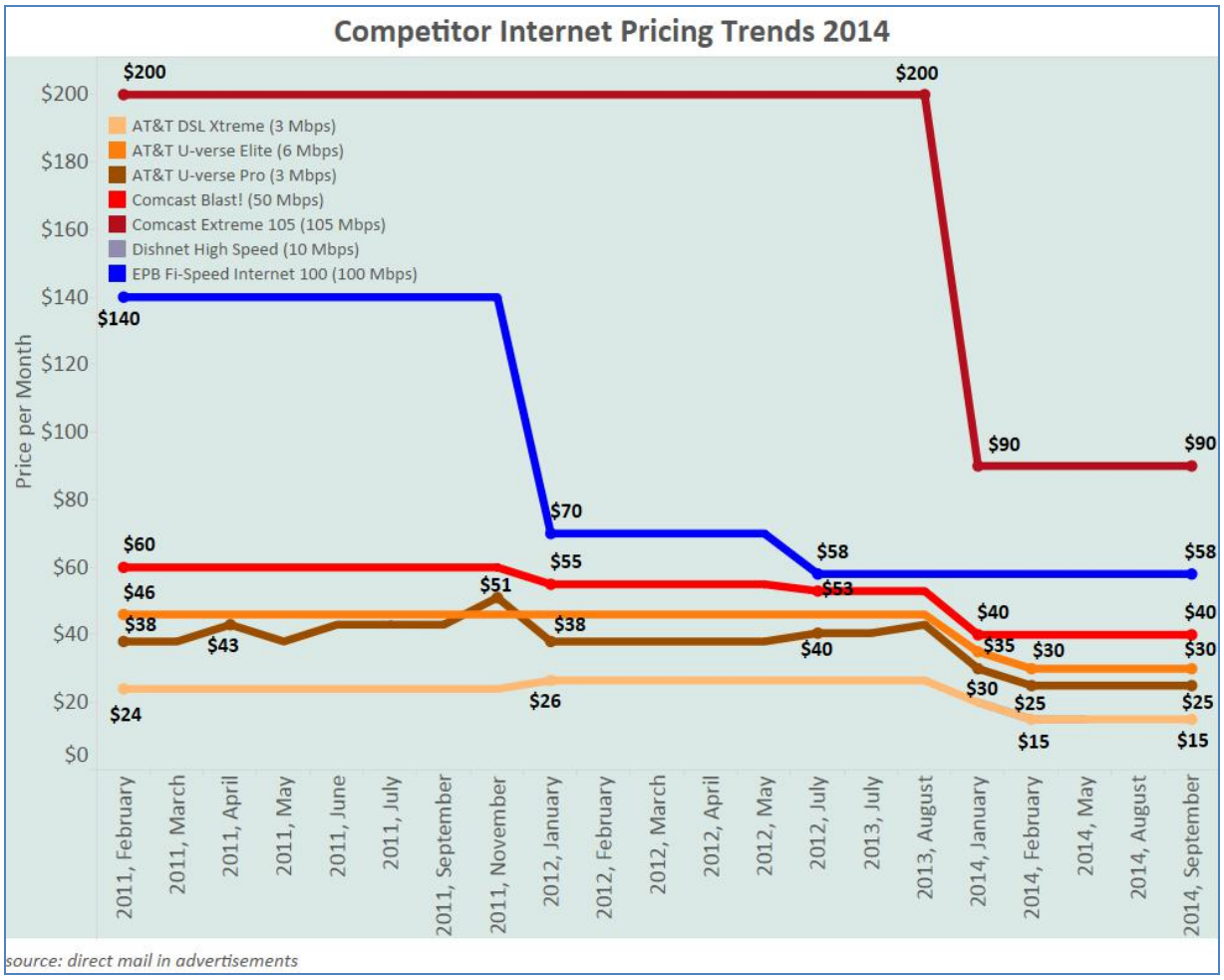

Figure 2. Competitor Internet Pricing

In particular, note that Comcast's 105 Mbps service, i.e. the only alternative high-speed option to the EPB fiber service, has dropped 55% over this period. The EPB 100 Mbps service has dropped from $140 per month to $58 per month, i.e. by 58.6%. In each case, the price drop has been much greater than the 20% anticipated competitive drop in price cited in Lobo et al (2006). Relative to an average price of $170 (i.e. $200 + $140 / 2) of these two providers in 2011, consumers pay about 56.8% less today, i.e. a savings of $96.5 per month. Annually, this translates to a cost savings of $24,854,154 for the 21,463 households that currently take the fiber triple play service.

Cumulatively, customer savings of $45.5 million stem from lower power bills and competitive pricing.

COMMUNITY EFFECTS

PUBLICITY

Since 2010, the "Gig City" has started to garner global awareness and media coverage. A sampling of media sources and articles is listed below:

The Guardian – How One City's Super-Fast Internet is Driving a Tech Boom
New York Times – Fast Internet is Chattanooga's New Locomotive
CBS Morning News – Which City has the Fastest Internet in the Nation?
Al Jazeera English – New Technology to Protect US Grid
Thomas Friedman column in the New York Times - Obama's Moment
CNBC – Rebooting Chattanooga's Fortunes
Atlanta Journal Constitution – Technology Thriving
Wired – Where High Speed Internet Meets Smart Grid
Fast Company – A Small City with a Smarter Grid
GreenTech Media – Top 10 Utility Smart Grid Deployments in North America
The Economist – The need for speed
Wall Street Journal – Cities start own efforts to speed up Broadband
Wall Street Journal – Getting "Smart" on Outages
Forbes – The New Metropolis: The New Urban Pioneers

This high quality exposure helps draw the attention of vibrant and innovative workers and entrepreneurial talent. It also draws business investment to the area. From September 2010 to August 2012, and September 2014 – March 2015, the City was covered in at least 1,134 stories reaching a total of over 1.8 billion viewers and readers as seen in the table below. We intrapolate the missing data from September 2012 to August 2014 to arrive at the advertising-equivalency value of this media exposure of $24.3 million as seen in Table 6.

Table 6. Gig Media Coverage Report

Month	Total number of stories	Circulation: Unique Visitors	Advertising Value
Sep 2010 to Aug 2012	137	434,729,808	$1,909,295
Sep 2014 – Apr 2015	994	1,370,907,334	$12,715,165.52
Total 2010 – April 2015*	**1,885**	**3,009,395,237**	**$24,374,101**

Sources: CoLab and EPB.
* Intrapolated for the period September 2012 to August 2014.

As a lower bound to this measurement, we exclude the intrapolated values from September 2012 to August 2014, in generating an advertising-equivalency value of this media exposure of $14.6 million.

ECONOMIC DEVELOPMENT

Jobs and Investments

The Chattanooga Area Chamber of Commerce collects data on announced new business investments and expansions in the community. This list is compiled from news media announcements and from direct contact with potential and existing firms.[29] The investment and jobs creation figures are those projected over the entire scope of the project which, in some cases, takes several years to complete. While most projects progress successfully and as announced, some do not. Those investments that either did not materialize after the announcement or companies that have closed since announcing their original plans have been excluded from this analysis.

The approach taken in this study has been to assume that 10% of announced project investment is realized in each year beginning with the announcement year. In other words, a $2,000,000 investment announced in 2014 would be fully invested/built out in 2023 at the rate of 10% in 2014, 20% in 2015, and so on. The same assumption is applied to job creation. This approach is somewhat *ad hoc* but likely errs on the side of being conservative. Table 7 shows the announced and realized investments and jobs from 2000 to 2015.

Table 7. Announced and Realized Investments and Jobs

Year	Announced New Investments	Announced New Jobs	Percent realized	Realized Investments	Realized Jobs
2000	$102,336,000	2,151	100%	$102,336,000	2151
2001	$114,450,000	905	100%	$114,450,000	905
2002	$198,413,500	1,332	100%	$198,413,500	1332
2003	$91,600,000	333	100%	$91,600,000	333
2004	$434,132,550	1,817	100%	$434,132,550	1817
2005	$69,380,000	1,373	100%	$69,380,000	1373
2006	$611,128,000	2,967	90%	$550,015,200	2670.3
2007	$423,630,000	1,538	80%	$338,904,000	1230.4
2008	$1,191,200,000	2,900	70%	$833,840,000	2030
2009	$200,330,000	895	60%	$120,198,000	537
2010	$155,220,000	2,817	50%	$77,610,000	1408.5
2011	$154,991,000	1,448	40%	$61,996,400	579.2
2012	$146,900,000	2,698	30%	$44,070,000	809.4
2013	$333,340,000	2,557	20%	$66,668,000	511.4
2014	$904,800,000	3,586	10%	$90,480,000	358.6
2015	$40,130,000	440	NA	NA	NA
TOTAL	$5,171,981,050	29,757		$3,194,093,650	18,046

[29] It should be noted that over the years this data has been compiled by different people at the Chamber. In particular, data for the year 2000 contain several "confidential" entries for investments rendering information for that year less reliable.

Since 2000, a total of 29,757 new jobs were announced in the Chattanooga area, corresponding to over $5.1 billion in new investments. We estimate that about $3.1 billion was effectively invested here in that period, creating 18,046 jobs.[30] From 2009 to 2014, we estimate that $461 million in new investments and 5,228 new jobs were actually created in this area (including 1,024 jobs attributed to new tech start-ups).

Among the firms investing in Chattanooga are Volkswagen AG ($1.6 billion and 4,000 jobs), Alstom Power Inc ($300 million and 360 jobs), and Amazon ($91 million and 1,249 jobs). In particular, VW has attracted 15 supplier firms to the city, which have created cumulatively 1,070 new jobs.

How many of these jobs and how much of this investment can be attributed to the fiber infrastructure in the community? This question is not easy to answer absent direct evidence from the relocating/expanding firms. However, evidence from corporate site selection surveys suggests that high-speed internet access and cost-efficient energy availability rank in the top 5 site-selection factors considered by firms.[31,32] This would suggest that the fiber optic investment made by EPB has had a significant impact in attracting companies to the area, consistent with the predictions in Lobo *et al* (2006 and 2009).

The firms include HomeServe USA, which was originally recruited to the area with the fiber optic system as an important decision-point, and Claris Networks, a cloud computing company that has expanded in Chattanooga because the fiber system allows them to serve customers both within and outside of the Chattanooga market less expensively by locating their technical infrastructure here.

When HomeServe USA and Claris Networks are combined with tech-oriented INCubator companies, the Lamp Post Group's companies, and a conservative estimate of local companies that have started with support from the Company Lab, the Chamber counts 91 companies that employ 1,024 people. They caution that this is likely a very conservative count because it only includes companies the Chamber and its economic development partners are in close or recent contact with.

In order to estimate the amount of new investment and jobs attributable to the fiber infrastructure, we consider a rough approximation of a range for the period 2009-2014.

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[30] Note that these estimates will differ from the BLS' QCEW figures primarily because our tables focus on new investments and related jobs only, whereas the BLS figures reflect additions and attritions to existing businesses as well. Moreover, the BLS data are unrelated to new investments made in the area.

[31] Availability of high-speed Internet access was not even on the chart in 2003. Today, high-speed Internet access is already considered primary infrastructure by companies that handle a significant amount of electronic data. Such companies could not even consider a community without this feature. Some federal government officials have even equated it to the need for electricity in the 1930s.

[32] http://msbusiness.com/2006/07/survey-examines-top-site-selection-factors/ and http://www.utahpulse.com/featured_article/survey-site-selection-consultants-say-labor-costs-and-incentives-most-important

To generate a lower bound on new investments and jobs attributable to the fiber infrastructure we adjust the realized number of new investments and jobs by the current residential take rate of data services (i.e. 43%). This measure suggests that $198,239,632 in new investments and about 2,832 new jobs can be attributed to the fiber optic infrastructure.

The likely upper bound on new investments and jobs attributable to the fiber infrastructure is the total realized investment and jobs in this period on assumption that high-quality and reliable communication and electric infrastructure are key to attracting new businesses to the community. We estimate $461.0 million and 5,228 in new investments and jobs over this period.

In summary, we estimate that between $198 million and $461 million in new investments and between 2,832 and 5,228 new jobs were created in Hamilton County due to the fiber infrastructure.

Taxes

The fiber optic division of EPB has also contributed to city and county coffers in the form of payments in-lieu of taxes (PILOT).[33] Additionally, a portion of the EPB electric division's PILOT are also attributable to the fiber infrastructure.[34] The total amount of payments in-lieu of taxes contributed over the period 2009-2014 is $25.77 million, as seen in Table 8.

Table 8. EPB Payments In-Lieu of Taxes due to Fiber

Division	2009	2010	2011	2012	2013	2014
Fiber optic	$228	$293	$465	$641	$759	$803
Telecom	$725	$929	$947	$906	$817	$742
Electric‡	$1,482	$2,650	$3,291	$3,305	$3,248	$3,537
Total	$2,435	$3,872	$4,703	$4,852	$4,824	$5,082

Figures in thousands.
Source: EPB Annual Reports. ǂ From Mike Kaiser (EPB)

Note that the taxes contributed to city and county coffers due to the fiber optic infrastructure are likely to be higher than reported here because private business growth is not considered. To the extent that high-speed broadband and the smart grid have contributed to economic development, some portion of private business taxes paid to the county could be reasonably attributed to the fiber infrastructure. We incorporate this adjustment in our "high" estimate by calculating the fraction of Hamilton County tax revenues ("Total General Revenues") attributable to the fiber infrastructure. To do so, we

[33] Since 2011, the fiber optic and telecom (phone) divisions have been reported separately in the annual reports.
[34] These estimates were provided by EPB.

first calculate the joint residential and commercial take rate for fiber as a fraction of the (latest) Hamilton County population for the four-year period 2011-2014.[35] This rate works out to 8.7%, 11.1%, 14.1% and 17.2%. We then multiply these annual rates by the annual Hamilton County tax revenues for the same period. Cumulatively, this yields a tax contribution of $75.29 million. We only include this estimate in the upper bound of the range of values reported.

In sum, we estimate that payments in-lieu of taxes paid to Hamilton County due to the fiber infrastructure were in the range of $25.7 to $101 million.

[35] We restrict this calculation to the period when fiber would have been widely available to the community.

The Entrepreneurial Ecosystem

Measuring economic development is at best an imprecise exercise. The technological transformation in Hamilton County and Chattanooga in particular, has resulted in the development of a unique entrepreneurial ecosystem. The following excerpts are taken from "Maximizing the Gig" (2014)[36]:

A long-time town of entrepreneurs, Chattanooga is now home to a new generation of startups, and just as crucial, successful exits. Thinking Media, a learning software development company, sold its KeyTrain workforce development product to ACT in 2010. In 2013, restaurant management software company QuickCue was acquired by Open Table just two years after its inception. Access America, a transportation logistics company with annual revenue exceeding $500 million and ranking #9 among the top 25 of Forbes' list of America's Most Promising Companies (February 2013), announced a merger with Coyote Logistics in early 2014.

Recent tech startups in Chattanooga range from an application looking to reinvent mobile banking (Sisasa) to a health insurance broker (American Exchange) to a social media platform looking to boost employee activity (LifeKraze). Nudge looks to promote healthy living through interactive web and mobile applications, Corpora uses Tweets and other public data to track the spread of illness, and Vigia uses mobile video-focused mobile apps for public safety professionals to enhance benefits of emergency services. Other tech startups include FanJam, a daily fantasy sports website, and Ambition which provides real time analytics and motivation to sales people through friendly competition.

The CO.LAB (Company Lab) originally began as a part of predecessor CreateHere's mission to make Chattanooga a more creative and vibrant city that would attract and retain creatives and entrepreneurs alike. After months of talking with successful entrepreneurs about their road to success, certain themes began to emerge: the importance of mentorship, access to capital for all stages of growth, access to talented specialists among others. CO.LAB was finally launched in September 2010 to take the entrepreneurial programs from CreateHere and combine them with a mentorship-driven startup accelerator – CO.LAB Accelerator. In May 2012, CO.LAB launched the entrepreneur track of the summer program *GigTank*, a 14-week entrepreneur accelerator program focused on utilizing Chattanooga's 1 Gigabit/second internet grid.

The 2014 *GigTank* launched several notable startups, among them GridCure and Feetz. GridCure has advanced to 500 Startups, a seed-fund and accelerator program based in Silicon Valley. Feetz is a finalist in the South by Southwest accelerator competition in Austin, TX, in March 2015.

Almost simultaneously, private partners began to emerge in the local community to fund new ventures. The Lamp Post Group (a venture capital firm founded and funded by a

[36] Courtesy Danna Bailey (EPB) and the Enterprise Center

group of young local entrepreneurs) decided to offer a $50,000 bounty to college students from around the country to come up with the best gigabit ideas. The inaugural GigTank business accelerator began attracting and supporting tech entrepreneurs throughout an intensive 12-week summer program.

In the past four years alone, Chattanoogans have raised over $50 million through the Chattanooga Renaissance Fund, Blank Slate Ventures, Spartan Ventures and the Jump Fund, the Southeast's only women-led fund earmarked specifically for women-led enterprises. SwiftWing Ventures, Chattanooga's newest venture capital group, aims to make investments in "early growth" startups that have already demonstrated proof of their business concepts. For these companies, SwiftWing is providing both capital and strategic guidance – helping new companies build the structure needed to scale quickly.

In an ongoing effort to explore the use of next-generation technology, the Mozilla Foundation selected Chattanooga to be one of the two cities included in the Mozilla Gigabit Communities Fund, allocating dollars and other resources for innovators to develop applications related specifically to education and workforce development.

In 2013, newly-elected Chattanooga Mayor Andy Berke formed a new entity focused solely on guiding community efforts related to the "gig": The Enterprise Center. In June 2015, the Enterprise Center announced the establishment of the Chattanooga Innovation District, calling it part of an "ongoing effort to solidify Chattanooga's growing standing as an ideal city for startup companies, technology and the next generation 'innovation economy."[37] In the meanwhile, the Annenberg Innovation Lab in Los Angeles and gigabit communities such as Austin TX and Burlington VT, have been collaborating with Chattanooga in efforts to maximize the use of the Gig for citizens and communities.

Chattanooga was recently selected as one of 25 cities to partner with the White House on the *US Ignite Initiative*, which is focused on moving the United States forward as a leader in developing high-speed broadband applications. Alongside US Ignite, Chattanooga and other gigabit cities are enthusiastically forging the gigabit future.

The evolution of the entrepreneurial ecosystem in Chattanooga is especially remarkable because the city does not have a top-tier research University, unlike Austin, TX, for instance. However, while the evolution of the entrepreneurial ecosystem bodes well for future economic development, it is difficult to quantify the benefit of this ecosystem uniquely. Moreover, it is even more difficult to tie the growth in this ecosystem to particular variables, such as high-speed broadband and the smart grid. However, anecdotal evidence points to a distinct and real cultural shift toward entrepreneurship that at least partially, must be attributable to cutting-edge infrastructure. We use estimates of venture funding by the local venture capital funds in the city of Chattanooga as a gauge of the entrepreneurial evolution in the city in recent times.

Data from Launch Tennessee, an organization with a mission to find and support promising startups in Tennessee, shows that there are seven venture capital funds located

[37] http://www.chattanoogan.com/2015/1/13/291936/Chattanooga-Is-First-Mid-Size-City-To.aspx

in Chattanooga currently. Data on one of these, Solas Bioventures, is currently unavailable.

Table 9. Venture Capital Funds in Chattanooga

Fund (start date)	Focus	Approximate amount (through March 2015)
Lamp Post Group (2010)	A venture incubator that provides both capital and mentorship to growing startups. Services include legal, accounting, HR, recruiting and downtown office space.	$30,000,000
Chattanooga Renaissance Fund (2012)	Looking for companies that are slightly more advanced and have made some progress since they're original plan in Chattanooga and surrounding cities	$3,000,000
Chattanooga Renaissance Fund II (2014)	Similar to the CRF.	$7,600,000
Blank Slate Ventures (2014)	Looking for disruptive, pre-revenue startups in the Chattanooga region.	$1,000,000 to $3,000,000
Spartan Ventures (2014)	Works with other companies but also launches its own products; Built technologies that they are looking for management team to take over.	$500,000*
Jump Fund (2013)	Group of women investing in female-led companies; Looking to make Chattanooga and Southeast the best place for a woman to start a business; Sees women as an untapped market of potential entrepreneurs	$2,500,000
SwiftWing Ventures (2014)	Looking to invest in the $1M range into companies that have come out of incubator programs and can grow quickly; Offering such large amounts of money to show that businesses can get this money in Chattanooga instead of having to go to New York or Silicon Valley; Will invest in company anywhere that will make good returns to bring capital back to Chattanooga to be reinvested	$2,000,000
Solas Bioventures	Provides liquidity for venture capital investments	$5,000,000*
TOTAL (approximate)		$46,100,000 to $53,600,000

Source: Fund websites and discussions with Presidents/Partners/CEOs/CFOs of the funds.
*excluded from lower range of values presented.

Launch Tennessee's Social Media & Research Coordinator, Taylor Dickenson, opines that the regional and national acclaim received by Chattanooga start-ups is disproportionately larger than the acclaim received by start-ups from other parts of the state. However, it bears noting that most start-ups do not critically depend on high-speed broadband for their success. Moreover, the venture funds listed above do not all invest

solely in Chattanooga-based ventures. However, a vibrant entrepreneurial culture that is supported by high quality communication infrastructure is a catalyst for many new ventures. Accordingly, we count the venture capital funding available in Chattanooga as a benefit stemming at least partially from the fiber optic infrastructure.

TELECOMMUTING

Telecommuting (telework) refers to working from home or satellite offices as opposed to commuting to a physical place of work. Research shows that telecommuting can contribute to time and cost savings as when employees share a reduced office space, use the same facilities on a rotating basis, share large files, access the corporate network from home, and reduced office space rental and parking expenses. Measurable benefits also stem from savings in transportation costs and the reduction in congestion and pollution costs.

Telecommuting has also been shown to facilitate group collaborative projects. Additionally, firms could induce well-qualified people to a region, and assist persons with disabilities who are unemployed or underemployed. These and other factors contribute to reduced absenteeism, and improvements in employee retention rates, thereby reducing recruitment and training costs.

According to Crandall and Jackson (2001), the quantifiable benefits of telecommuting are the savings in transportation costs – both the time and expense of the worker, and the reduction in congestion and pollution costs imposed on others. Harder to quantify benefits include improvements in worker productivity and the expansion of employment opportunities for people with disabilities.

CASE STUDY[38]: Daniel Ryan, Software programmer

Daniel Ryan, a software programmer in his early 30s, works with high profile companies like Microsoft and Google on the West Coast, but the programmer enjoys living in Chattanooga and has wrestled with the choice of moving to California to further his career or staying in area he has grown to love.

> *"With Fiber optics, it is now realistically feasible for me to work remotely," says Ryan of his choice to stay in the area.*

Video conferencing with colleagues around the globe is now a feasible alternative to traveling or moving to conduct face to face meetings. "When I subscribed to a cable network, video conferencing wasn't plausible. Our connection was almost always either dropped or throttled. Using Skype, calls were paused or re-started regularly, making working remotely a challenge," says Ryan of his previous provider. Ryan spends six to seven hours a week video conferencing with peers across the country in real-time, allowing efficient collaboration. Without Fiber optics, Ryan conducted only one to two meetings per month remotely. Today, he averages 5-times as many remote meetings.

When Ryan does choose to travel, he can work from anywhere in the world utilizing the IP address that EPB Fiber gives its customers. Attaining an IP address from competitors was cost prohibitive for Ryan, but now he can download his files to any computer quickly and reliably.

[38] EPB Case Studies: 30 June 2011. Print.

Hamilton County Estimates

In Hamilton County, about 94.4% of the labor force or 154,117 people commute to work by driving or taking mass transit (see Table 10). The average one-way commute takes 21.65 minutes (0.3608 hours) implying a distance of 14.43 miles at a speed of 40 miles per hour. However, almost 26% of all workers commute more than 30 minutes to work. We estimate 75% of commuters travel 14.43 miles and 25% travel 20 miles to work for a weighted average travel distance of 15.82 miles each way per day.

Table 10. Transportation in Hamilton County, Tennessee		
Transportation	**Hamilton, TN**	**United States**
Commute Time	**21.65**	**25.44**
COMMUTE MODE		
Auto (alone)	**83.21%**	**76.14%**
Carpool	**9.29%**	**10.03%**
Mass Transit	**0.96%**	**4.98%**
Bicycle	**0.28%**	**0.56%**
Walk	**2.10%**	**2.82%**
Work at Home	**3.20%**	**4.27%**
COMMUTE TIME TO WORK		
Commute Less Than 5 min.	**2.71%**	**3.28%**
Commute 6 to 9 min.	**9.38%**	**10.37%**
Commute 10 to 14 min.	**15.42%**	**14.42%**
Commute 15 to 19 min.	**19.86%**	**15.52%**
Commute 20 to 24 min.	**18.84%**	**14.78%**
Commute 25 to 29 min.	**7.97%**	**6.08%**
Commute 30 to 34 min.	**14.04%**	**13.58%**
Commute 35 to 39 min.	**2.32%**	**2.73%**
Commute 40 to 44 min.	**2.10%**	**3.65%**
Commute 45 to 59 min.	**4.25%**	**7.52%**
Commute 60 to 89 min.	**1.78%**	**5.56%**
Commute greater than 90 min.	**1.34%**	**2.51%**
Source: http://www.bestplaces.net/transportation/county/tennessee/hamilton		

The methodology below follows Crandall and Jackson (2001).

The savings in travel time can be computed as follows:
# of telecommuters x hours/day[39] x days/year x Half average hourly wage rate

The savings in travel cost can be computed as follows:
# of telecommuters x Average roundtrip commute miles per year x average cost per mile[40]

[39] Round trip.
[40] Based on the University of Tennessee at Chattanooga Travel Policy as of March 2015

The reduction in congestion costs can be computed as follows:
Proportion of commuting labor force that telecommutes x %reduction in commuting x peak multiple[41] x Half of total congestion costs per year[42]

We estimate the number of telecommuters in Hamilton County using EPB's telework product as a proxy.

From 2011, the number of firms/users taking this product has increased from 30 to 529, growing at a CAGR of 62.3%, as seen in the chart below.

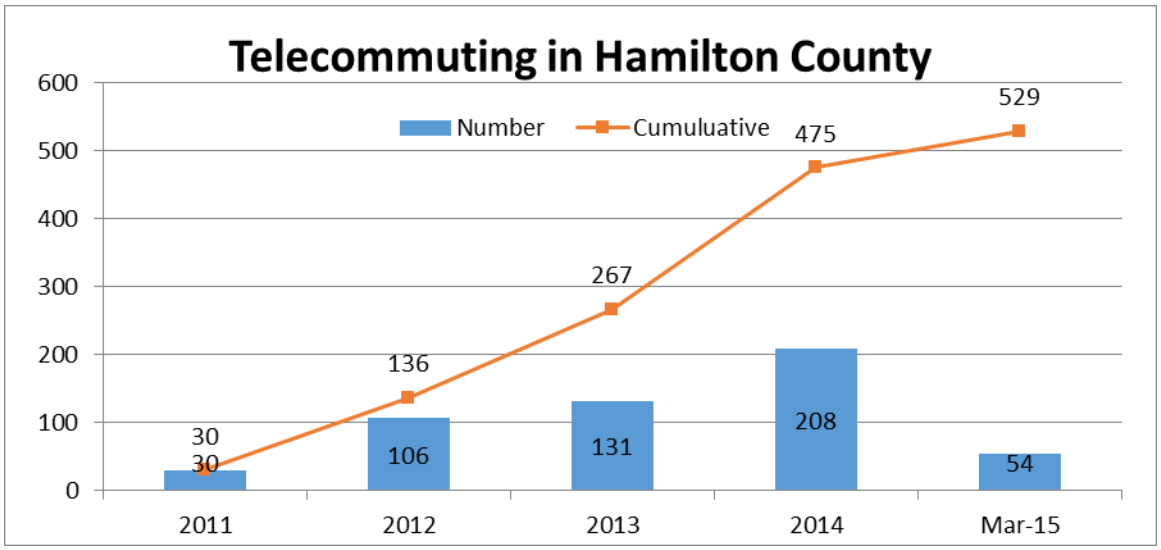

Figure 3. Telecommuting Trends

While our methodology is likely to underestimate the true number of telecommuters in the county, it does tie telecommuting effects directly to fiber optic services being offered by EPB.

The largest telework programs in Chattanooga belong to BCBST, Unum, Cigna and EPB. We assume that teleworkers work 5 days a week from home but are required to report to the office twice a month. Accordingly, each teleworker is estimated to work 216 days from home out of a total of 240 work days in the year.

[41] From Crandall and Jackson (2001) who use Krugman's approach.
[42] Source: Texas Transportation Institute's 2010 Urban Mobility Report. This is the estimate of average congestion cost for small urban areas (with populations less than 500,000). Available at: http://mobility.tamu.edu/ums/report/

Table 11. Savings from Telecommuting					
	2011	**2012**	**2013**	**2014**	**2015E**
Cumulative # of teleworkers	30	136	267	475	529
Average commute miles / year	3417.12	3417.12	3417.12	3417.12	3417.12
Average commute minutes / trip	25.9	25.9	25.9	21.65	21.65
Cost per mile	$0.510	$0.555	$0.565	$0.560	$0.560
Average hourly earnings[43]	$22.91	$23.37	$23.83	$24.34	$24.84
Savings in travel time	$64,084	$296,347	$593,250	$901,103	$1,024,160
Savings in travel costs	$104,564	$515,848	$1,030,979	$1,817,908	$2,024,575
Reduction in congestion costs	$525,164	$525,164	$525,164	$525,164	$525,164
Total	$693,812	$1,337,359	$2,149,393	$3,244,176	$3,573,899
Notes: Average commute time / trip from 2009-2014 is a national average from the Census Bureau. Cost per mile is as per UTC's travel policy.					

The annual benefit of telecommuting in 2015 is estimated to be $3,573,899. The cumulative savings from telecommuting from 2011 to 2015 was $10.99 million.

Data limitations

It is likely that telework will grow substantially in the near future. Consequently, gathering data on telework programs at different businesses and metrics used to track the effectiveness of such programs would be useful. Such programs are tied to technological advances, although to varying degrees. Data from local area firms would help to clarify the growth potential of telework programs.

[43] http://ycharts.com/indicators/average_hourly_earnings

HEALTHCARE

The benefits of high-speed internet connectivity are significant in the provision of healthcare.[44] Broadband-enabled telemedicine encompasses real-time remote patient consultations; remote monitoring of patients' vital signs and conditions; the storing and forwarding of critical health information for analysis and diagnosis (e.g. MRI results and electronic health records [EHRs]); the provision of specialized services over long distances (e.g. teledentistry, telepharmacy, telepsychiatry, and mHealth); and the wide availability of health information to patients and caregivers. The Journal of the American Medical Association recently reported on a study finding that the use of telemedicine services in ICUs resulted in lower mortality rates, lower rates of preventable complications, and shorter stays in ICUs and hospitals generally.

A recent poll of healthcare quality experts found that the biggest issues patients will face in light of staffing shortages are spotty care, longer waits for primary care physicians, and medical errors.[45] According to a recent survey by Intel, 89 percent of healthcare executives expect telemedicine to transform the U.S. healthcare system in the next decade.

Telemedicine – Stats, Data and Observations cites the following[46]:

- Chronic conditions are on the rise across all age groups and currently account for 75 percent of the nation's healthcare costs. By 2025, chronic diseases will affect half of the U.S. population, an estimated 164 million Americans.
- A shortage of healthcare professionals threatens to place additional strain on the healthcare system. HHS predicts that healthcare staffing shortages will increase significantly after 2014, when 32 million more Americans become insured as mandated by the federal healthcare reform law. AAFP predicts a shortage of about 40,000 physicians by 2020. With the senior population set to double by 2050, such a shortage could create significant problems for the healthcare system.

A 2008 study from the University of Texas Medical Branch[47] showed that the U.S. health care system can save $4.28 billion from the elimination of patient transfers alone (this benefit of high speed Internet does not include the potential savings from remote monitoring or interpretative services). These include transfers from one hospital emergency department to the emergency room, from correctional facilities to physicians' offices, from nursing homes to emergency rooms, and from nursing homes to physicians' offices. Telemedicine also significantly helps in the case of expectant mothers seeking prenatal care from a distant hospital, as seen in the work of Regional Obstetrical Consultants (ROC) in Chattanooga (see the Case Study later). Similarly, high speed Internet allows physicians to connect with distant specialists for real-time guidance in

[44] http://www.capsil.org/files/Telemedicine%20and%20Telehealth%20Outcomes%20Research.pdf
[45] http://www.broadbandexpanded.com/policymakerfiles/telemedicine/Telemedicine_Stats&Data.pdf
[46] http://www.broadbandexpanded.com/policymakerfiles/telemedicine/Telemedicine_Stats&Data.pdf
[47] http://telehealth.utmb.edu/presentations/The%20Telehealth%20Promise-Better%20Health%20Care%20and%20Cost%20Savings%20for%20the%2021st%20Century.pdf

emergency situations, potentially saving lives by eliminating the delay of long ambulance rides when seconds count, such as during a stroke or heart attack.

In fact, about a third of rural patient hospitalizations take place in urban hospitals and patients from rural areas reported that that they are forced to travel, on average, 60 miles to visit a specialty care physician.

The real-time transmission of medical imagery enables the interpretation of MRI, ultrasound, X-rays, and other diagnostic procedures to be performed remotely with much greater speed and efficiency.

Studies show that patients benefit from high-speed broadband. For instance, in 2000, more than half of all Internet users had used the Web to obtain medical or health information. That number rose to 60 percent by the end of 2007. As of 2011, 80 percent of Internet users now gather health information online, while 27 percent have reportedly tracked their weight, diet, exercise routine, or some other health symptom online.

Another study found that nearly 43 percent of paper prescriptions contained an error. However, the percentage of errors dropped to just 7 percent for prescribers using an electronic system.

A 2012 study in New Zealand[48] concluded that the savings in the healthcare domain included lower hospital admission and test costs, fewer emergency room visits, lower travel- related costs, lower long-term prescription drug costs, faster access to physicians and faster care delivery leading to savings in government expenditure on healthcare. The result was a $5.9 billion consumer surplus over 20 years. Similarly, a Penn State University study of one group of diabetes patients showed estimated hospital costs of $87,327 for patients monitored through telehome health compared to $232,872 for patients that received traditional homecare from a visiting nurse.

A white paper from the Internet Innovation Alliance estimated that remote home health monitoring for one group of diabetes patients cut costs for hospital care 69 percent, from almost $283,000 to approximately $87,000 per patient.

A Veterans Administration study of one remote monitoring effort showed a 40 percent cut in emergency room visits, a 63 percent reduction in hospital admissions and a 60 percent reduction in the number of hospitals. And, a health care study by economist Robert Litan projected that remote broadband-based monitoring had the potential to cut hospital, drug and out-patient costs by 30 percent.[49]

Whitacre (2011) proposes a methodology to capture the effects of telemedicine in rural communities in four states. He isolates savings associated with: 1) hospital cost savings

[48] http://www.tmcnet.com/tmc/whitepapers/documents/whitepapers/2013/6687-building-benefits-broadband-how-new-zealand-increase-social.pdf
[49] http://www.internetinnovation.org/files/special-reports/Advancing_Healthcare_Through_Broadband-Neuberger.pdf

from outsourcing radiology procedures, 2) transportation savings for patients, 3) savings from not having to miss work, and 4) benefits of additional lab/pharmacy work performed locally. He estimates that telemedicine services contribute between $20,000 and $1.3 million annually to these local communities, with an average benefit of $522,000.

CASE STUDY: Dr. James Busch, Radiologist

Dr Jim M Busch is a radiologist who moved from Boston to Chattanooga in 2004. When medical imaging transitioned to Picture Archiving and Communication System (PACS) in the early 2000s, all imaging went digital and the need for reliable and large bandwidth became critical. In Boston, he paid around $15,000 per month for a T3 connection which is 33 percent slower than a 100 Mbps connection. After moving to Chattanooga, ***his telco budget has dropped significantly*** *while increasing efficiency and improving the quality of medical care.*

He pointed out that limits to telemedicine stem from compensation mechanisms and compliance requirements. A remote teleconference between doctor and patient cannot occur over SKYPE or GoToMeeting, absent appropriate privacy and compliance safeguards. Moreover, physicians are not currently compensated for telemedicine unless no specialist physician is available within a 10 mile radius of the patient.

The effectiveness of emerging telehealth technology is directly tied to broadband speed. Dr. Busch is utilizing EPB's 1 Gigabit VLAN product for both his office and his home to provide a telehealth business in the Chattanooga area which seeks to increase the quality of care, decrease Emergency Room wait time, and reduce hospital stays.

Radiology is a data intensive field; each examination averages 250 megabits in size. Using a connection meeting the FCC's basic standard[50], this data transfer would take over a minute to download and over four minutes to upload. EPB's network transfers the data both upstream and downstream in three seconds. Dr. Busch and his team process about 200,000 exams and millions of images annually, creating the need for the rapid transfer of 50 million Megabits per year in the area. EPB's infrastructure saves the radiologists up to 60 hours a year.

Conventional turn- around time for these exams is one to four hours in an Emergency Room and between 10 – 24 hours in a hospital setting. Every day, the whole system allows for a less than 15 minute turn around per STAT exam with the average exam completed in less than an hour. In emergency situations in which every second counts, the quicker turnaround results not merely in cost cutting efficiencies but also in life saving opportunities. Traditionally, patients requiring these tests may have had to stay overnight, waiting for results. This technology makes it possible to reduce the length of hospital stays or even avoid staying in the hospital entirely, reducing payment burdens on patients and taxpayers.

[50] Download speeds of at least 4 Mbps and actual upload speeds of at least 1 Mbps – FCC Sixth Broadband Deployment Report

CASE STUDY: Regional Obstetrical Consultants (ROC)

Dr. Dave Adair is the CEO of ROC, headquartered in Chattanooga. Dr. Adair, along with five other highly trained physicians, runs this high-risk obstetrics practice. In 2009, with support from BCBST's Solutions for Obstetrics in Rural Counties (STORC) initiative, ROC began a telemedicine practice. Today, they serve 17 remote sites in Tennessee, Georgia and North Carolina. By connecting patients to high-risk obstetrical specialists, the STORC program seeks to reduce unnecessary patient transportation and hospitalizations as well as the length of stay in neonatal intensive care units. Moreover, each teleconsultation takes about 15 minutes less than a normal face-to-face consultation/visit, which takes on average, 45 to 60 minutes.

ROC maintains EMR, PACS and telemedicine services on their gigabit internet service provided by EPB. Backups are maintained on- and off-site and disaster recovery services are maintained using co-location services. Tele-consultations are delivered via a 10 Mbps symmetrical connection. The connectivity and bandwidth is constrained by internet access service at the remote locations. Each remote site has 1-2 advanced care personnel and 1-2 stenographers. The team of physicians visits the remote sites once a week. The average monthly cost of maintaining a telemedicine site (e.g. IT, rent, personnel, transportation, etc.) is $39,593.

Table 12 contains select information about the ROC telemedicine sites in Tennessee and Georgia.

A total of 47,298 hours were saved from patients not having to drive to Chattanooga, an average of 3.56 hours per patient. When the savings in consultation time is added, this time savings adds up to 51,044 hours. The time savings can be quantified in terms of wages earned (or not lost) on account of telemedicine. At a median wage rate of $19.25 per hour, the cumulative benefit amounts to $982,589.

Furthermore, patients avoided driving a total of 2,364,891 miles due to teleconsultations over this period, at an average of 165 miles per patient per visit. The savings from not driving, at an average cost of $0.55 per mile, amount to $1,300,690.[51]

Moreover, portable equipment costs are significantly lower. A typical precision ultrasound machine costs $250,000, whereas a portable unit costs $46,925. ROC uses 8 portable units at a cost of $375,400. By contrast 8 stationary ultrasound machines would cost $2 million.

[51] Note that these estimates of savings are partial because data on the number of (multiple) visits per patient were not available at the time of writing.

Table 12. ROC Telemedicine Summary

	Number of patients tele-consulted					Savings			
Site	**Distance (miles)†**	**2009 - 2012**	**2013**	**2014**	**2015**	**Total Hours**	**Time Savings**	**Avoided Miles**	**Miles Savings**
Other	82.79	5,822	NA	NA	NA	20736	$399,161	964,007	$530,204
Blairsville, GA	100.1	NA	264	396	94	3208	$61,745	150,951	$83,023
Blue Ridge, GA	80.5	NA	373	541	130	3623	$69,737	168,084	$92,446
Calhoun, GA	51.3	NA	534	396	142	2468	$47,504	109,987	$60,493
Cartersville, GA	75.7	NA	733	564	48	4409	$84,872	203,633	$111,998
Cleveland, TN	31.6	NA	212	396	7	931	$17,924	38,868	$21,377
Cookeville, TN	101	NA	555	403	131	4672	$89,932	219,978	$120,988
Jellico, TN	166.4	NA	95	128	15	1644	$31,640	79,206	$43,564
McMinnville, TN	74.1	NA	947	1023	260	7167	$137,969	330,486	$181,767
Winchester, TN	64.4	NA	396	275	103	2187	$42,106	99,691	$54,830
TOTAL		5,822	4,109	4,122	930	51,044	**$982,589**	2,364,891	**$1,300,690**

Source: ROC

†One-way from the remote site to Chattanooga. Total hours = number of patients times round-trip distance divided by 50 mph. Time saved is based on an average hourly wage of $19.25. Avoided miles = round-trip distance times number of patients. Miles savings = Avoided miles times average cost per mile ($0.55). Data for 2015 is through March.

Data Limitations

Ideally, to compute some of the benefits identified in the literature, we would need data on:

- The number and type of images processed by tele-radiologists; from this information RVU data can be gathered and priced
- The number of full-time equivalent (FTE) employees at these entities so that an RVU/FTE measure of efficiency can be measured
- Average hospital wait time and stay time for patients; from this we can compute savings in time and money more accurately
- Average distance of patients (receiving telemedicine services) from the physicians' offices (similar to that of ROC)
- Telemedicine practices in Emergency Medicine and in treatments of stroke and heart attacks, and for patients with diabetes

Hamilton County Effects

The healthcare benefits of high-speed broadband in Hamilton County are varied and fairly unclear at the time of writing. Absent some of the data required to generate estimates, we approximate some of the benefits as described below.

1. Consumer Surplus
    a. Annual telco budget savings: for hospitals, doctor's offices and radiologists who take the 100 Mbps or Gigabit VLAN fiber optic service, we compare the cost of EPB 1 Gig point-to-point VLAN service to competitor pricing for a similar service.[52]

Note that this number underestimates the true cost savings because there is no easy way to tell the number of users on each VLAN that benefit from the service.

    b. Cost of data service: There are 616 health-related companies in town that take the EPB fiber service. Here costs of the service are compared to the average cost of all other internet service options in Chattanooga

2. Annual efficiency cost savings: Based on the tele-radiology case study, we estimate 60 hours per year saved times the number of radiologists taking EPB 100 Mbps or higher service times the median hourly wage for radiologists (i.e. $178) [53]
3. Telemedicine savings based on the ROC case study:
    - Savings in patient time (does not include avoided missed days of work)
    - Savings due to miles avoided

Note that because ROC does not use high-speed broadband currently due to constraints at the remote sites, we only consider 25% of the savings from (3) above as relevant to our study.

[52] The cost savings can be calculated as follows: EPB 1-Gig VLAN cost is $2,500 while Comcast's similar product (with a 36 month commitment) is $4,599. The cost savings each month is therefore $2,099 per customer.
[53] Source: http://www1.salary.com/radiologist-hourly-wages.html

Table 13. Healthcare benefits of High-Speed Broadband			
	# of firms	**Savings: Low**	**Savings: High**
Medical VLAN customers	22	$396,000	$924,000
Other Medical fiber customers	594[54]	$7,840,800	$32,788,800
Tele-radiology efficiencies	20[55]	$213,600	$213,600
Telemedicine: savings due to time saved†		$245,647	$245,647
Telemedicine: savings due to drive miles avoided†		$325,173	$325,173
TOTAL		**$9,021,220**	**$34,497,220**
Notes: Absent time series data on the variables, we estimate a one-time benefit as of March 2015. †represents 25% of the computed value.			

In sum, a partial analysis of healthcare services benefiting from high-speed broadband reveals a likely range of benefits from $8.9 million to $34.4 million.

[54] 616 health-related companies that take the EPB fiber service excluding the 22 VLAN customers previously accounted for.
[55] Estimate of number of radiologists engaged in tele-radiology in Hamilton County.

EDUCATION

"The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn and relearn." – *Alvin Toffler, Futurist*

High-speed broadband networks have helped expand communication between teacher/school and students and between teacher/school and parents. However, the integration of educational technology is largely dependent upon the quality of school Internet connections. Most school Internet connections currently support many concurrent users. As a result, the bandwidth available per student is often very low and under the minimum threshold that the FCC has designated as basic broadband.[56]

School and classroom access to computers is critical since many students lack such equipment and broadband connections at home. Indeed, the OECD recently highlighted the existence of a second digital divide, in which lower levels of home computer use lead to inadequate technology skill development for students.

The U.S. Department of Education recently reported that in households with broadband, "children ages 6-17 reported that high-speed access affected both their online and offline activities, including schoolwork." Since getting broadband, 66 percent of participating children spent more time online, 36 percent watched less TV, and 23 percent [improved their] grades."[57]

A recent report issued by the U.S. Distance Learning Association reveals numerous ways that broadband connectivity is equalizing educational opportunities for students of all ages.

- Schools that have and use Internet are facing the fact that 21st-century education is driven by data and the way that it is stored.
- Data storage on campuses grows by over 50 percent each year.
- Better duplication practices can save terabytes of storage, improve data access times, and increase overall storage efficiency.

Digital technologies hold much promise for the future of higher education. According to a New Horizon Report, "The implications for informal learning are profound, as are the notions of 'just-in time' learning and 'found' learning, both ways of maximizing the impact of learning by ensuring it is timely and efficient."

CASE STUDY: Brainerd Baptist School

With the one gig service that EPB allows all Hamilton county schools, Brainerd Baptists' students enjoy the benefits of tele-lessons and interactive learning. Teachers are able to

[56] One recent study estimated the national average access speed per student to be just 6.5 Kbps. At these speeds, many of the potential cost-savings, quality improvements, and cutting-edge educational applications are inaccessible.

[57] http://www.ntia.doc.gov/files/ntia/publications/exploring_the_digital_nation_-_americas_emerging_online_experience.pdf

focus more on the students because traditionally manual tasks such as attendance and performance tracking are now automated.

> "EPB has changed everything for us," says Information Technology Director Bradley Chambers. "Today, all of our administrative files, emails, and financial records are hosted in the cloud. Those options were available before EPB, but they weren't viable due to speed constraints."

In savings related to email, the school estimates that $40,000 will be saved over 10 years. In addition to the email savings, an upgrade to an expensive $10,000 server would have been required without fiber. Instead, $10,000 bought 50 Mac Books, 15 iPads, 30 iPod touches and 3 Promethean boards.

> *"Kids today learn differently from even my age group, so it doesn't make sense to hand them traditional materials and expect them to work well. A child here can read the Gettysburg address, or they can press a button to hear it or click a link to find more detail. The ability to consume information is limitless with this bandwidth" says Chambers of the new devices.*

The Promethean boards are smart versions of yesterday's chalkboards that download new lessons and encourage participation through digital response devices that record individual student performance in real time.

Chambers believes that the symmetrical 400 Mbps EPB product has resulted in significant time savings and efficiencies. During a tornado recently, the school was still able to maintain communication systems and process payroll remotely. Moreover, cloud-based hosted software are easily updated and upgraded, avoiding the need to maintain local servers. He can now use his time on strategic decision-making and training, rather than software maintenance. Sharing and uploading documents is extremely fast and efficient. Moreover, the school has had only 3 outages in the past 5 years. Doing all he does now with slower connectivity would require at least one additional part-time employee, i.e. a personnel cost saving of about $29,909 per school year.[58] *Chambers believes this benefit is scalable to other schools in the county.*

CASE STUDY: Battle Academy School

Battle Academy, a magnet elementary school located in downtown Chattanooga, educates both affluent and at-risk children. The school relies heavily on technology to teach lessons, streamline administrative tasks, conduct teacher/parent communication and support disadvantaged children with special programs. EPB supplies Battle Academy with 100 Mbps VLAN.

Magnet Technology and Arts Education Facilitator Scott Rosenow estimates that increased bandwidth saves two hours out of each eight-hour day in productivity for Battle's teachers.

[58] Calculation: $20.77/hour x 8 hours/day x 180 school days per year.

> *"That increased productivity not only saves the school anywhere from $20 - $40 per teacher per hour but also gives students more time with their instructors" said Rosenow.*

Supported by adequate bandwidth, children can now simultaneously watch live streaming events on large screens in each classroom, Skype with authors across the country, and connect with other children worldwide. Quality images matter in the classroom, where students engage in virtual science experiments, real-time views from the Hubble Space Station illustrate space lessons, and new species are discovered with vivid, life-like images.

To help its at-risk students, Battle uses Fast ForWord, a web based program, to awaken parts of the brain that may not have been stimulated in early childhood. Before high-quality bandwidth, these students may not have been able to access the program as freely.

In May 2015, The National Science Foundation awarded a $300,000 grant to the Public Education Foundation and University of Southern California School of Cinematic Arts to support the first-in-the nation cross-country collaboration using the Gigabit network.[59] With USC, students at STEM School Chattanooga are designing experiments to study the effects of human activity on microbial ecosystems both here at home in Chattanooga, as well as a continent away in the Pacific Ocean. Students at STEM School Chattanooga will manipulate a 4K video microscope at the University of Southern California. Students will be able to harness both the power of an ultra-high-definition microscope and the expertise of a Tier 1 research university using Chattanooga's Gigbit network.

The Chattanooga Public Library has transformed itself from a 20th century institution to one that encourages innovation by offering a public laboratory and educational facility with a focus on information, design, technology, and the applied arts. While traditional library spaces support the consumption of knowledge by offering access to media, the Chattanooga Public Library has combined the traditional approach with one that supports the production, connection, and sharing of knowledge.

In more recent developments, The University of Tennessee at Chattanooga, working in partnership with The Enterprise Center and US Ignite, has acquired and activated a GENI (i.e., Global Environment for Network Innovations) rack. The GENI rack is linked with similar racks in 60 other leading universities in smart cities in the U.S. and internationally. The racks act collectively as a programmable nervous system for researching and deploying the next generation of the Internet and cloud computing.

UTC joined an elite group of universities with the installation of the Chattanooga GENI Rack, which allows for a high-speed, distributed, virtual environment for development and research of next generation technologies. UTC is the only non-research one campus in the country to house a GENI system.

[59] http://www.chattanoogan.com/2015/5/11/300159/STEM-School-Links-To-4K-Microscope-At.aspx

The Chattanooga rack is unique in that it will be able to connect to Chattanooga homes and small businesses with gigabit Internet service from EPB Fiber Optics. This arrangement will enable Chattanoogans the opportunity to develop, test and provide feedback on advanced next-generation Internet applications in education, healthcare and public safety.[60]

CASE STUDY: The University of Tennessee at Chattanooga

At the University of Tennessee at Chattanooga (UTC) high-speed internet (Gig) access has produced productivity gains, according to Chief Technology Officer, Monty Wilson. The campus has not had an outage since July 26, 2009. He cites benefits related to:

- *Monitoring safety:*
  - *Fewer false firing alarms*
  - *State-of-the-art classroom alert beacons that promote student safety*
- *Facilities:*
  - *quicker fixes and reduced manpower costs*
  - *Swipe card access in buildings which improve security and reduce the cost of replacing keys*
  - *Video-monitoring on campus*
  - *Connectivity in the classrooms*
- *Redundancy which provides reliable service*

Tom Ellis, Assistant Vice Chancellor at UTC, points out that:

- *The over 500 security cameras on campus require significant bandwidth. They deliver campus safety and preparedness.*
- *Additionally, swipe card access does not require high bandwidth but delivers greater flexibility in fixing problems (e.g. avoided cost of rekeying). A north campus housing building recently needed rekeying when the master key was lost at a cost of $100,000 for 1600 doors.*
- *Off-campus connectivity of IRIS/BANNER to UTK software delivers benefits as well.*

The campus is preparing to transition to VoIP and appears to be well-positioned to support the Internet of Things.

A study out of New Zealand recently pointed to savings in the education domain stemming from lower costs of skill enhancement, as well as reduced cost of course materials and savings on field trips. The result was a $3.6 billion consumer surplus over 20 years.[61]

CASE STUDY: Hamilton County Department of Education

Jason McKinney is the Deputy Administrator of Education for the City of Chattanooga. He oversees the county's afterschool literacy program. This includes 18 Youth and

[60] http://blog.utc.edu/news/2015/03/chattanooga-geni-rack-installed-utc-2/

[61] http://www.tmcnet.com/tmc/whitepapers/documents/whitepapers/2013/6687-building-benefits-broadband-how-new-zealand-increase-social.pdf

Family Development (YFD) Centers, and some non-profit and faith based programs. The County uses Lexia, an online program that students are able to utilize from any internet connected device. The initiative employs 16 Academic Coaches for 12 hours per week to work with this program, homework assistance, and other educational programming.

McKinney says, "Each center is open until 8, but the educational programs typically run for 3 hours per night from Monday through Thursday. We typically see around 30 kids per night for all 18 centers. We have more that come to the centers, but the computer rooms and the Academic Coaches' capacity is maxed out at around 30."[62]

The YFDs receive 100 Mbps service from EPB. Prior to the availability of high-speed broadband, the County was unable to offer Lexia and related services. Without broadband access, "the honest answer would be that we just couldn't do the program. If we wanted to have a similar impact, we would need at least 2 additional teachers per site. However, we still could not meet the needs like we are now." At an average cost per teacher of $20/hour, this cost would amount to $12,480 per teacher per year.[63]

Hamilton County Effects

1. Increase in teacher productivity measured by hours saved with faster internet connections (i.e. 1 hour per full time teacher per day):

Assuming a productivity improvement as described by Rosenow and Chambers, of one hour per day per full-time teacher in the county at the hourly rate of $20.77,[64] amounts to a benefit of $59,506 for the school system each day.[65] For the 180 school days, the total benefit could be as much as $10,711,089. Absent individual school data, we assume that only 25%, i.e. $2,677,772, of this gain may be attributable to high-speed broadband and can be realized annually.

2. Savings in email and server upgrades avoided (e.g. Brainerd Baptist School):

Additionally, cloud-based software relieves the need for local servers. At a cost of updating/maintaining such servers of $1,000 per year per school, the benefit for the 76 schools in Hamilton County amounts to $76,000 per year.

3. UTC benefit from avoided re-keying of a dormitory building amounts to $100,000.

4. Savings in Hamilton County afterschool literacy programming: At the rate of two teachers per year for the 18 YTD centers, this saving amounts to $449,280.

Together, these benefits amount to **$**3,303,052 annually and to $9,909,157 over a three year period from 2012 to 2015.

[62] The cost to purchase unlimited licenses for these centers runs about $150,000 for 3 years. This cost is covered by private and faith-based sponsors.
[63] $20/hr x12 hr/week x 52 weeks = $12,480
[64] http://work.chron.com/hourly-wages-teachers-2044.html
[65] There are 76 schools and 2,865 full-time teachers in the district. See: http://www.teachersalaryinfo.com/tennessee/teacher-salary-in-hamilton-county-school-distrct/

CIVIC SERVICES: E-Government and Public Safety

High speed broadband can enable governments to increase the number and level of public services available to citizens by putting new and existing services online. Broadband allows local government jurisdictions to host Internet community forums and provide multimedia communication services on websites. The potential benefits of e-government result from savings in time and transportation costs involved with visiting local government offices, and savings associated with the reduction in government paperwork.

Broadband services are particularly beneficial to the disabled community. In addition to promoting greater civic participation and reducing the isolation that many disabled individuals feel, video phones with closed caption technology can greatly increase the ability to communicate for those within the deaf community. High-resolution computer screens and voice-activated programs can aid the visually impaired, and with software such as eBooks, everything from novels to textbooks can be downloaded. For the physically disabled and the elderly, the Internet, especially with a broadband connection, provides a means for them to connect and communicate with the world.

Broadband infrastructure can also be a critical element in assisting a rural community to compete economically within the overall global business climate. Broadband infrastructure assists rural communities in attracting businesses, providing health care to residents and accessing government services. Broadband can serve as a critical link to information and news for communities that have limited newspaper, radio and television station choices.

Additionally, advanced broadband infrastructure would promote security and public safety. Such services as remote video monitoring of home, children, pets, and remote video monitoring of schools and businesses will enable greater public security. At a broader level, biometric screening at designated entry points/sensitive facilities, and remote surveillance of borders, ports, and airports will promote national security. Importantly, local benefits could include assistance to police, fire, first-responders and emergency personnel in crisis situations.

Hamilton County Effects

A quantifiable benefit to Hamilton County stems from the use of the Intelligent Transportation System (ITS). The project is seeking funding from the Department of Transportation to achieve two goals: 1) to identify optimal strategies to minimize congestion and 2) to minimize delay during incidents leading to reductions in secondary accidents within the transportation network. The project requires significant bandwidth and is expected to have a six-year build out period. We have not included values associated with this project in our summary estimate because this benefit is yet to be realized.

The regional ITS will be able to bring together the mapping communications connection on a single web accessible map or smart phone application and provide information in

real time on the status of the transportation network. The regional ITS will also be able to get out messages in a timely fashion so that users of the transportation network have the opportunity to make an informed choice on the route or perhaps even the mode they should utilize. Subsequent phases of the ITS project will deploy a CCTV network throughout the region to monitor and detect incidents. This information, in turn, can be shared with first responders and other agencies.

Emission reduction can be envisioned along two lines: 1) emission reduction due to traffic signal timing improvement for normal daily travel conditions, and 2) emission reduction due to effective rerouting of congested traffic on freeways to local streets during incidents.

Traffic Congestion is one of the number one complaints from citizens using the 311 system. A January, 2010 study by the news source "*The Dailybeast"* ranked the section of Interstate 24 in the area of US 27/Rossville Blvd. /Exit 180 as 47th out of 75 worst for hours of bottleneck congestion. That rate was 20 hours weekly spent in congestion during peak hours over the time spent in that corridor during free-flow hours.[66]

The publication *"Governing"* ranked Chattanooga 37th out of 100 for worst Friday afternoon rush hour commute among American cities.[67] These studies have the Chattanooga Region competing with several other large cities across the United States in terms of the most congested roadways. This level of congestion comes at a price, not only in lost time, wasted fuel and more harmful emissions, but it also affects quality of life for citizens and the ability to compete economically with other cities. As indicated on the fueleconomy.gov website "Idling gets 0 miles per gallon and costs as much as $0.04 per minute, (per vehicle)."[68]

It is estimated for this project that substantial savings can be obtained in Annual Fuel Savings while achieving major Emissions Reductions. Over an anticipated 15-year service period of the project the public is expected to receive considerable benefits in fuel savings of approximately 86 million gallons.

The project would generate additional, significant benefits such as time saved due to congestion/delay reduction, reduction in vehicle maintenance costs (due to vehicles operating more efficiently, less stop and go on each vehicle), and reduction of secondary crashes caused by primary incidents, which would likely exceed the benefits in fuel savings.

[66] http://www.thedailybeast.com /articles/2010/01/19/americas-75-worst-commutes.html
[67] http://www.governing.com/blogs/by-the-numbers/worst-friday-afternoon-rush-hour-commutes-american-cities.html.
[68] http://www.fueleconomy.gov/feg/pdfs/guides/FEG2014.pdf

BUSINESS EFFECTS

Business Productivity and Efficiency

One of the most touted benefits of advanced technology pertains to gains in productivity (Stiroh, 2001). The U.S. Department of Commerce reported that IT accounted for at least half of the productivity gains in the U.S. economy since 1995.[69] Oliner and Sichel (2000) conclude that IT investment was responsible for two-fifths of the growth in total factor productivity and 68 percent of the accelerated growth in labor productivity. The attendant efficiency gains stemming from enhanced productivity comes from savings in personnel and time, streamlined and automated process flows, fewer errors, economies of scale and from lower processing costs per unit.

Today's Internet economy is large and growing fast by every measure. In 2012, the Boston Consulting Group estimated the size of the Internet economy in the G20 countries at around US$ 2.3 trillion or 4.1% of GDP in 2010; by 2016, this could nearly double to US$ 4.2 trillion. In 2011, McKinsey estimated that the Internet accounts for 3.4% of total GDP and one fifth of all growth in GDP for the G8 countries plus five major economies (Rep. of Korea, Sweden, Brazil, China, and India – McKinsey Global Institute, 20113). Taking into account the spillover effects of broadband could boost these estimates further, as broadband connectivity is also argued to impact labor productivity positively.

Besides the benefits that come directly from deploying and using broadband services, communities that have advanced broadband services may have a competitive edge in attracting and retaining businesses. That edge can become a significant competitive factor between businesses, as well as serve as an important aspect of economic development (Pociask, 2005). As previously noted, the evidence from Hamilton County is supportive of this notion.

According to an International Finance Corporation (IFC) jobs study from 2013, firms in developing countries investing in Information and Communications Technology (ICT) achieved both higher labor productivity and job growth. In fact, the World Bank estimates that advances in the telecommunications sector have contributed significantly to Africa's GDP-per-capita growth, more so than investments in roads or power.[70]

According to surveys conducted by Render, Vanderslice and Associates (2010), 77 percent of FTTH users with home-based businesses said their business was more efficient or would not be possible without FTTH. In 2013, it was estimated that:[71]

- 97% of Internet users look online for local products and services.
- 9 out of 10 part-time business owners rely on the Internet to conduct their businesses.

Today, all business is e-business. E-business refers to the integration of information and communications technology into every stage of the value chain and includes the use of

[69] https://www.esa.doc.gov/Reports/DIGITAL.pdf
[70] http://futurehrtrends.eiu.com/report-2014/changing-nature-work/
[71] http://static.googleusercontent.com/media/www.google.com/en/us/economicimpact/reports/2013/ei-report-2013.pdf

advanced ICT to attract and retain customers, to streamline firm operations such as supply chain or inventory management, to automate business processes, and to collect, analyze and share business intelligence about customers and company operations with employees, suppliers, and business partners. High speed broadband is a prerequisite for the successful diffusion of e-business services. It is commonly expected that it includes facilitating new ways of customer-supplier interaction, reduced transaction costs, and increased operational efficiency.

The anecdotal evidence of these benefits in Chattanooga is increasing.

Daniel Ryan, the software programmer previously mentioned, believes EPB's 30/30 symmetrical product saves him three days annually. On a cable provider's network, it took Ryan up to 30 seconds to save a file on the West Coast; on EPB's network, the file saves in six seconds. The time that is saved pays for the programmer's monthly subscription fee for fiber optic service. He can now work more efficiently, he can take on more work.

CASE STUDY: Claris Networks

Claris Neworks' CTO, Aaron Sherrill, said Claris made a strategic decision to be in Chattanooga. The company helps takes customers to the cloud, a process that requires significant bandwidth. Consequently, the end-user experience does not suffer. An example would be doctors' offices where EMR can be managed on the cloud.

The cost of bandwidth in Chattanooga is significantly lower compared to elsewhere. By way of an example, Sherrill pointed out that in Knoxville, a 100 Mbps service from AT&T would cost $1,400 per month whereas a comparable service through EPB costs $300, a $1,100 savings. The savings are magnified when comparing Gigabit service. Whereas, such service might cost between $5,000 and $7,000 per month through AT&T, the same costs $1,400 per month through EPB, a savings of between $3,600 and $5,600 per month.

CASE STUDY: Cornerstone Community Bank

Randy Dover is the VP of IT services for Cornerstone Community Bank. He oversees six locations of the bank, including five branches. As a bank with fewer than $1 billion in assets, Cornerstone outsources its online banking to an outside firm.[72] However, Dover is convinced that the superior gig speed and reliability of the EPB service his bank subscribes to results in reduced outage time savings and cost savings. He estimates that the reliable high-speed broadband service results in about 70-90 minutes of savings per employee per day. He claims to have had only one outage with his fiber service several years ago. Moreover, he opines that other banks in the area that take the gig service are probably experiencing similar benefits.

In the case of Cornerstone, 80 minutes saved (on average) daily by 110 employees over 240 days, translates to annual productivity gains of $735,680 at a median wage rate of $20.90 for banking personnel.

[72] AS400 machines required for the purpose are cost-prohibitive for smaller banks.

One of the biggest benefits of enhanced bandwidth is in the area of disaster recovery. The bandwidth makes such recovery quicker, more reliable and significantly cheaper. The company has the capability to fix problems almost instantaneously, can bridge networks and so can recover data from individual machines located at multiple sites.

A proxy for this benefit in Hamilton County is the Co-Location revenues EPB generates from hosting client data and information on their own racks and servers.

Low bandwidth networks require extra hardware to cache and backup files and data and result in a lot of duplication of work at multiple locations. Firms with more sites/locations, stand to benefit more from cloud-based services and experience greater savings.

Large-scale Gig bandwidth enhances productivity by enabling firms to do more with the same amount of personnel. One way to think about this is to ask the following question: *to achieve the same level of productivity that high-speed bandwidth permits, how many additional employees would be needed using narrower bandwidth?*

Data Limitations:
Firms are apt to not reveal competitive information especially as it pertains to efficiency and cost savings. Cleaner estimates of efficiency gains and cost savings are possible if the following data were available:

- Actual efficiency metrics (time saved, dollars saved) for each firm in the footprint
- Actual uses of broadband services by different firms
- Disaster recovery practices and costs of local firms

Absent firm-level data, we use a rough approximation of these efficiency gains. We consider savings based on an assumption of 5% of total employee time saved per day,[73] i.e. 96 hours per year based on an eight-hour day and 240-days per year. At a median hourly wage rate of $19.25, this amounts to a savings of $2,336.64 per firm per year.

Hamilton County Effects:

1. Efficiency gains calculated as follows: 5% of employee time saved per day per firm x median hourly wage rate
2. Disaster Recovery services, proxied by EPB Co-Location Revenues
3. Consumer surplus: [74]
    - Bandwidth cost savings: High-speed broadband data service cost savings x # firms taking the fiber data service (ex-VLAN customers)[75]

[73] Note that this is more conservative than the 70-90 minutes suggested by Dover.
[74] Consumer surplus here represents what consumers are paying relative to what they would have to pay elsewhere. The latter is used as a crude measure of WTP. We calculate the cost savings by comparing the cost of fiber internet service relative to non-fiber service in Hamilton County.
[75] Gig service cost savings per month = $6,000 - $1,400 = $3,600; 100 Mbps service cost savings per month = $1,400 - $300 = $1,100.

- VLAN cost savings: VLAN customers x (Competitor cost of service - EPB cost of service)[76]

Table 14. Commercial Productivity Gains and Cost Savings

Benefits	2011	2012	2013	2014	2015	Total
Commercial fiber data customers	1,667	2,628	3,746	4,591	4,774	
VLAN customers†	28	45	64	78	96	
Efficiency gains	$3,080,616	$4,856,544	$6,922,608	$8,484,168	$8,822,352	$32,166,288
Disaster Recovery (Co-Lo Revenues)	$233,353	$413,345	$773,581	$861,391	$679,436	$2,961,106
Bandwidth Cost Savings	$21,915,371	$34,549,247	$49,247,139	$60,356,010	$62,761,837	$228,829,603
VLAN Cost Savings	$230,360	$363,159	$517,654	$634,424	$659,712	$2,405,310

Source: EPB
† For 2011-2014, these are estimated based on the proportion of VLAN to all commercial fiber customers in 2015. Data for 2015 is through March.

The cumulative benefits as calculated for 2011-2015 amount to $266,362,307. We treat this value as an upper bound. As a lower bound on the value, we exclude the efficiency gains described above because they represent an estimate without firm-specific data.

[76] Comparative price information was provided by EPB. A typical point-to-point EPB VLAN service costs $2500 per month. The comparable service provided by Comcast is $4599 per month. Note that healthcare firms taking the EPB VLAN service have been excluded from this computation because they were included in the Healthcare section of the report.

UTILITY EFFECTS

Smart Grid Effects

According to smartgrid.gov, the electric grid is a network of transmission lines, substations, transformers and more that deliver electricity from the power plant to one's home or business. What makes a grid "smart" is the digital technology that allows for two-way communication between the utility and its customers. Like the internet, the Smart Grid consists of controls, computers, automation, and new technologies and equipment working together. In particular, these technologies work with the electric grid to respond digitally to quickly changing electric demand.

A smart grid permits a cleaner and more resilient and efficient electrical system. As pointed out in Lobo *et al* (2011) the Smart Grid plays an important role in mitigating electrical system emergencies, avoiding blackouts and increasing system reliability, reducing dependency on expensive imports, providing relief to the power grid and generation plants, avoiding high investments in generation, transmission and distribution networks and thereby leading to environmental protection.

In 2008, EPB began planning to modernize the electric system and to construct one of the first and largest Smart Grids in the United States. The Smart Grid called for new capital expenditure of $163.2 million over five years for fiber optic build-out, additional electronics, distribution automation, SCADA upgrade and the AMI initiative (Lobo, 2009). In November 2009, EPB received a federal stimulus matching grant in the amount of $111.6 million from the Department of Energy to expedite the implementation of the Smart Grid. By 2012, the Smart Grid was fully built out.

In a report filed with the Department of Energy in 2014, EPB cited the following key benefits of the smart grid:[77]

Reduced Operating and Maintenance Costs
Reduced Meter Reading Costs
Improved Electric Service Reliability
Reduced Costs from Equipment Failures and Theft
Reduced Truck Fleet Fuel Usage
Reduced Greenhouse Gas and Criteria Pollutant Emissions

[77] https://www.smartgrid.gov/sites/default/files/doc/files/EPB%20Final%20Project%20Description%20-%2020140422%20reformatted.pdf

The realized incremental value of the Smart Grid to EPB and its customers can be summarized as follows:

Table 15. Smart Grid Benefits			
	Chart code	**Annual Average**	**2012-2015 Total**
Reduced operating and maintenance costs	O&M	$1,600,000	$4,800,000
Avoided manual switching costs	AMI	$40,000	$120,000
Automated switching: Fuel and Labor cost savings	AMI	$1,800,000	$5,400,000
Reduced outage minutes	Outage	$43,500,000	$130,500,000
Major events (1 per year)	MajEvt	$23,209,664	$69,628,991
Reduced peak demand	DSM	$2,285,340	$9,190,688
Reduced power theft	Theft	$5,419,990	$16,259,970
Reduced Greenhouse Gas and Criteria Pollutant Emissions	Pollution	$455,324	$1,821,295
TOTAL		**$78,310,317**	**$237,720,943**

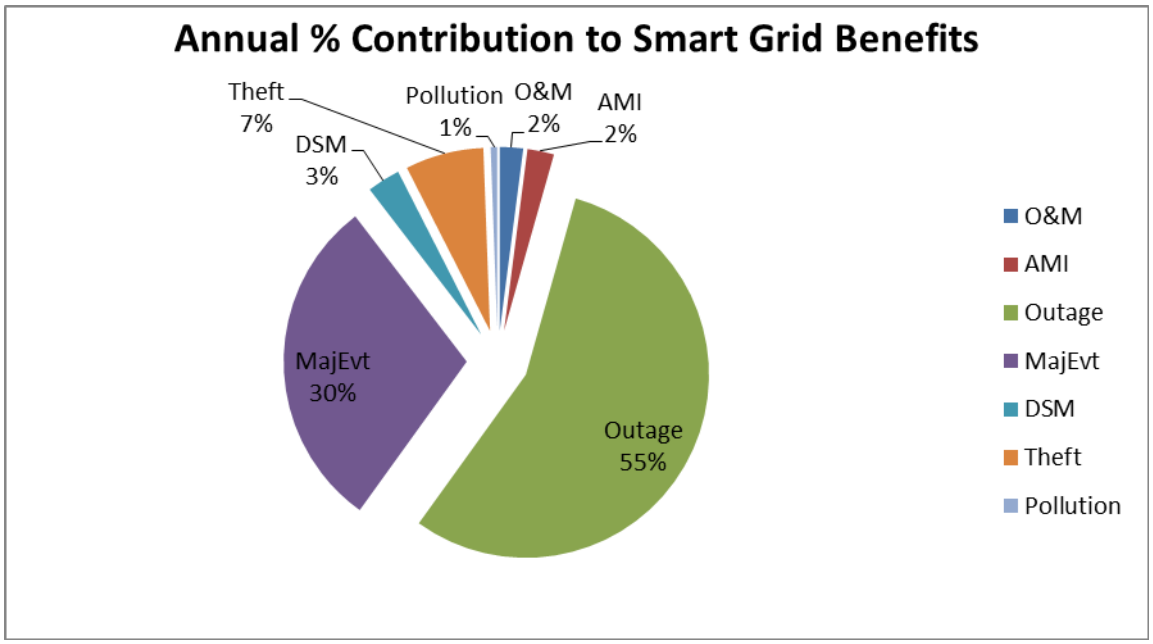

Figure 4. Smart Grid Benefits

Reduced operating and maintenance costs: According to EPB, the utility has realized $1.6 million in annual operational cost savings through automation of meter reading. The automated switching has significantly reduced the need to send staff into the field during and after storms to identify damage locations, isolate the damage, and restore the unaffected sections. In one severe storm that occurred July 5, 2012, EPB realized savings of over $1 million in overtime costs associated with the restoration effort. Over the three year period from 2012-2015, these benefits aggregate to $4.8 million.

It bears noting that the electric system at EPB has realized over $12 million in average annual operational cost savings due to O&M allocations to the Broadband and Telecom divisions from 2012-2014. These are reflected in customer savings from avoided rate hikes.

Table 16. Electric System: O&M Reduction

$ '000s	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Broadband O&M reduction	2,112	5,639	7,635	9,742	10,350	14,249
Telecom O&M reduction	1,328	1,594	1,753	2,095	1,945	1,961
Total O&M Reduction	**3,440**	**7,233**	**9,388**	**11,837**	**12,295**	**16,210**

Source: EPB. Data for 2015 is through March.

Avoided manual switching costs: Furthermore, avoided manual switching costs have saved the utility approximately $40,000 annually. Additionally, fuel and labor cost savings associated with automated switching resulted from 357,203 truck rolls / total miles avoided. This translates to an annual cost savings of $1.8 million, according to EPB.

Table 17. Savings in Fuel and Labor from Automated Switching

AMI truck rolls avoided	AMI Miles Avoided	Switching Truck Rolls Avoided	Switching Miles Avoided	Total Truck Rolls Avoided	Total Miles Avoided	Fuel and Labor cost savings
2,116,878	343,347	6,928	13,856	2,123,806	357,203	$1,800,000

Source: EPB

Outage minutes reduced: The single largest benefit of the smart grid has been manifest in outage minutes being reduced. During major and minor storms or disruptions of any kind, the smart grid enables a quick diagnosis and often, a remote solution. When scaled to their footprint, EPB estimated the cost of outage to be about $100 million based on a study conducted by the University of Berkeley. By the summer of 2013, EPB had achieved a 43.5% reduction in outage minutes. Panel A of Table 18 shows that as many

as 116 million minutes of outage time, i.e. roughly 241,754 work-days, were avoided due to the smart grid.[78]

Using the DOE's ICE calculator, this outage minute reduction showed an annual benefit of $43.5 million for the community. For the 2012-2015 period, this benefit amounts to $130.5 million.

Panel B of Table 18 also shows customer interruptions avoided, i.e. customers that were automatically restored (usually in a few seconds) or customers that did not experience an outage at all that would have previously. From 2011 through March of 2015, about 749,495 customers avoided interruptions in their power service due to the smart grid.

Table 18. Outage Reduction due to Smart Grid

A. Customer Minutes Avoided

Event	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Storm	3,057,999	3,096,757	36,976,226	36,633,684	0	79,764,666
Non-storm	1,377,121	4,570,752	7,905,058	11,741,673	10,682,509	36,277,113
Total	**4,435,120**	**7,667,509**	**44,881,284**	**48,375,357**	**10,682,509**	**116,041,779**

B. Customer Interruptions Avoided

Storm	12,520	31,505	42,589	45,774	0	132,388
Non-storm	28,961	83,607	129,846	195,032	179,661	617,107
Total	**41,481**	**115,112**	**172,435**	**240,806**	**179,661**	**749,495**

Source: EPB. Data for 2015 is through March.

Major weather events: However, these metrics do not tell the whole story because the ICE calculator does not factor in major weather events.[79] A joint EPB-Oak Ridge National Lab study of a major event on July 12, 2012 revealed that with automation, EPB was able to reduce customer outages by 55% and outage costs by 33%. The overall avoided cost from outages due to major events was estimated to be in excess of $23 million per event. At an average of one major weather event per year, the total benefit from smart grid automation amounts to $69.6 million over the period 2012-2015.

It bears noting that as a city-owned utility, the benefits attributed to EPB on account of the smart grid effectively accrue to the community that EPB serves. In particular, the benefits from stemming the costs of major weather events accrue mostly to businesses and households in terms of a reduction in lost productivity and economic activity.

[78] For each electric outage EPB records the number of customers affected and the length of the outage. The number of customers affected multiplied by the length of the outage equals the "customer minutes" of outage. Customer Minutes Avoided is the number of minutes of outage that have been reduced due to the automation.

[79] A major weather event is defined as an event that exceeds reasonable design and/or operational limits of the electric power system.

However, we include these benefits in this section of the paper because they are attributable to the smart grid infrastructure.

Demand-side management: The Smart Grid facilitates the use of automated switching and demand-side management (DSM) programs. These technologies and programs play an important role in mitigating electrical system emergencies, avoiding blackouts and increasing system reliability, and promoting environmental protection. Thus it provides significant economic, system reliability and environmental benefits. Society benefits when DSM is green. Reduced energy usage can directly translate into less air pollution, less carbon emissions, and a way to lower the potential environmental threats associated with climate change, even though off-peak energy needs are typically met from coal facilities.

Reduced peak demand: Voltage control allows EPB to reduce peak demand by an average of 20 megawatts per month, resulting in $2.285 million in wholesale demand savings annually (see Table 19). From May 2011 to March 2015, the total savings has amounted to $9,190,688. Moreover, the reduced peak demand over this period resulted in about a 9,246 MWh reduction in electricity consumption.

Pollution reduction: Electricity accounts for 78 percent of commercial CO_2 emissions according to the EIA.[80] Research has found that DSM programs can have positive and significant impacts on environmental quality. Johnson (2007) illustrates an example in which a DSM program reduces consumption by 1,000,000 kWh, which is equivalent to 632 metric tons of carbon.[81] She points out that these savings are also equivalent to 71,982 gallons of gasoline saved.

For Hamilton County, this reduction in pollution can be quantified to about $455,324 per year.

Table 19. Savings from Reduced Peak Demand and Reduced Pollution

	2011	2012	2013	2014	2015	Total
Peak MW reduced	160.68	237.12	255.83	268.84	98.73	1,021.19
Total peak cost reduction	**$1,446,098**	**$2,134,035**	**$2,302,425**	**$2,419,560**	**$888,570**	**$9,190,688**
Peak MWh reduced	2,014.37	2,470.13	2,236.36	1,763.40	761.76	9,246.02
Average price of gas per gallon	$2.95	$3.12	$3.00	$1.81	$2.30	
Total reduction in pollution	**$427,746**	**$554,752**	**$482,932**	**$229,749**	**$126,116**	**$1,821,295**

Source: EPB Annual Reports. Data for 2015 is through March.

[80] www.eia.doe.gov/neic/press/press298.html
[81] http://www.marketdevelop.com/docs/white_paper_program_implementation.pdf

Reduced costs from theft**:** Remote meter reading allows for more frequent identification of electricity theft. EPB estimates this benefit to be roughly 1% of annual revenues or $5,419,990 annually (see Table 20). [82,83]

Table 20. Power Theft Reduction

	2010	2011	2012	2013	2014
Electric Revenues	$473,767,000	$535,582,000	$544,177,000	$535,968,000	$545,852,000
Theft (1%)	$4,737,670	$5,355,820	$5,441,770	$5,359,680	$5,458,520

Source: EPB Annual Reports. Data for 2015 is through March.

Other Societal Benefits

Lobo (2011) points out that the implementation of a Smart Grid provides direct benefits to the end consumers of electricity. For instance, a consumer will be able to decide whether to run her dishwasher in the afternoon, when rates are higher, or at night, when rates are lower. The smart grid will also improve the adoption of renewable energy sources. However, many of these benefits accrue to society in general and are not limited to the end consumers. For instance, if the consumer installs solar panels on her roof, she might be able to sell excess energy back to the utility, which could then be delivered to the national electrical grid.

A modernized Smart Grid allows for environmental and health benefits, but also enables connection of distributed generation (with photovoltaic arrays, small wind turbines, micro hydro, or even combined heat power generators in buildings); incorporating grid energy storage for distributed generation load balancing; and eliminating or containing failures such as widespread power grid cascading failures.[84] The digital devices within the grid can decide how to best allocate power, depending on the demand, and they may be able to control devices attached to the grid.[85]

As a testament to the effectiveness of the Smart Grid in Chattanooga, the US Department of Energy (DOE), Oak Ridge National Laboratory and EPB announced in October 2014, the beginning of a partnership that will use Chattanooga's smart grid as a living

[82] https://www.epb.net/flash/annual-reports/2014/EPB-Financials-2014.pdf

[83] A more robust methodology for calculating this theft would be to calculate the Non-Technical System Losses as the difference between Total System Loss and Technical Losses. Moreover, the incremental benefit of the smart grid would have to be evaluated relative to system losses prior to AMI installations. However, these estimates are not currently available.

[84] http://en.wikipedia.org/wiki/Smart_grid

[85] In a simple example, a smart grid would recognize that a lot of people in one area were running air conditioners because it was hot, and opt to shuttle more power to that part of the grid. Furthermore, the smart grid might have the ability to shut down unused escalators and elevators in commercial buildings to free up power, or to adjust thermostats used for climate control to make energy usage more efficient.

laboratory for testing new energy technologies.[86] Since then, Georgia Tech, UT Chattanooga and UT Knoxville have signed MOUs to join this partnership.

Under the agreement with EPB and DOE, Oak Ridge National Laboratory will apply its technical expertise in such areas as data analytics, control systems, cybersecurity and high-performance computer modeling to test new smart grid technologies and processes on the electric grid in Chattanooga, allowing EPB to further capitalize on its smart grid investment.

[86] https://www.epb.net/news/news-archive/doe-epb-ornl-begin-new-partnership/

CONCLUSION

Scope and limitations

This study seeks to compare the estimates of the net benefits of the fiber infrastructure as modeled in Lobo (2011) to the realized economic value in Hamilton county, and Chattanooga in particular. The study examines a 3- to 4-year period spanning 2011 to March 2015. The methodology is focused on capturing the realized *incremental effects* of high-speed broadband and a smart grid. This means that measured effects adjust for the counterfactual case of having an alternative infrastructure in place, i.e. broadband, as opposed to high-speed broadband, and a traditional instead of a smart electric grid.

While every effort has been made to be as systematic as possible in capturing the value to the various stakeholders, the study remains incomplete mostly because there does not currently exist a holistic theory to guide the empiricist in capturing the value of internet access. The task gets more challenging because of a lack of data at the local level, and sometimes even at the national level, and a dearth of metrics to capture the value of high-speed internet connectivity.

A particularly difficult empirical question relates to the impact of high-speed broadband availability and the Smart Grid on the in-migration of skilled labor into Chattanooga. RelocateAmerica found that the city is attracting skilled labor at a rate about 30 percent faster than the national average. These people are baby boomers and members of the millennial generation and those who are characterized as the young, creative class - the driving force behind new, innovative businesses. Quantifying the reasons for such relocations is an important additional issue that further research must address.

Where do you look for the value of speedy internet connectivity? This study is organized along four planes: households, community, businesses and the utility. Our approach has been to examine areas indicated in Lobo (2011) and references therein, that are most likely to be impacted by expanded bandwidth, such as healthcare, education and business productivity, and to develop metrics appropriate for those sectors/areas with available data.

Findings

We find that over the period 2011-2015, the fiber infrastructure has generated incremental economic and social benefits ranging from $865.3 million to $1.3 billion while additionally creating between 2,800 and 5,200 new jobs. We find that the realized benefits have exceeded the projected benefits by at least 27 percent and, possibly, by as much as 95 percent. These estimates translate to benefits of between $2,832 and $3,762 per county resident. Moreover, between 100 percent and 180 percent of the projected job creation has been realized in Hamilton County over this four-year period.

About 80% of the recorded gains to the County are driven by new investments, business efficiencies and from the many benefits of the smart grid. Relative to the predictions found in the literature, telecommuting, healthcare, education and civic services have lagged in generating significant benefits to the community.

Our calculations show that the community benefits the most (46%), followed by businesses (23%), the utility (22%) and households (9%). However, these categories are not mutually exclusive as pointed out in the methodology section of the paper.

This analysis suggests that the true economic value of the fiber infrastructure is much greater than the cost of installing and maintaining the infrastructure. As measurement methods improve, new pockets of value will likely be discovered which will add to the values reported in this study.

Looking Forward

Currently, Chattanooga faces a *Gigabit Catch-22*: You need very-demanding technologies to make the most of a gigabit, but you need a gigabit connection to inspire the creation of those same technologies. Moreover, the city needs other cities to catch up. Chattanooga, however, is well positioned to take advantage of likely developments in advanced communication infrastructure.

The Internet at such robust upload and download speeds offers up the possibility of immersive education (say, interactive Chinese instruction beamed throughout a school district), health care applications (checking the vital signs of severely ill patients remotely), explorations in arts and culture (historian David McCullough, of Truman, delivering a lecture on the history of Jackson County)[87], wired homes (smart energy meters tied to every appliance), i.e. "the internet of things", collaborative research (genomic databases shared by scientists the world over), improved municipal services (firefighters equipped with tablets displaying 3D renderings of burning buildings), and much more yet to be imagined.[88]

The Pew Center's Internet, Science and Tech division published "*Killer Apps in the Gigabit Age*," in October 2014.[89] They asked experts "How could people benefit from a gigabit network?" David Weinberger, a senior researcher at Harvard's Berkman Center for Internet & Society, predicted, "There will be full, always-on, 360-degree environmental awareness, a semantic overlay on the real world, and full-presence massive open online courses. Plus Skype won't break up nearly as much." Others opined that people's basic interactions and their ability to 'be together' and collaborate will change in the age of vivid telepresence—enabling people to instantly 'meet face-to-face' in cyberspace with no travel necessary. Augmented reality will extend people's sense and understanding of their real-life surroundings and virtual reality will make some spaces, such as gaming worlds and other simulated environments, even more compelling places to hang out. The connection between humans and technology will tighten as machines

[87] In 2014, T-Bone Burnett, a Grammy Award winner, performed "The Wild Side of Life" from a Los Angeles studio with Chuck Mead, a founder of the band BR549 who was on stage in Chattanooga. Annenberg Innovation Lab Director, Jonathan Taplin said, "They sang a song together over 2,000 miles apart. That's the power of gigabit Internet. I think we're just beginning to think of the possibilities of what this thing can do."

[88] http://www.nlc.org/find-city-solutions/city-solutions-and-applied-research/infrastructure/gig-city-usa-bringing-google-fiber-to-kansas-city

[89] http://www.pewinternet.org/2014/10/09/killer-apps-in-the-gigabit-age/

gather, assess, and display real-time personalized information in an 'always-on' environment. This integration will affect many activities—including thinking, the documentation of life events ('life-logging'), and coordination of daily schedules. Specific economic and social sectors will be especially impacted; health/medicine and education were mentioned often.

A National Economic Council report dated January 13, 2015 opines that over the longer term, broadband adoption fuels a virtuous cycle of Internet innovation. This cycle begins when new applications of the Internet create demand for more bandwidth, resulting in a wave of network-level innovation and infrastructure investment. As more bandwidth becomes available, application-sector innovators find new ways to use that capacity, creating additional demand, leading to another round of network investment, and so on. While it is impossible to know what the next bandwidth-hungry killer application will be - perhaps it will be the "Internet of Things" or immersive virtual reality — both history and economic theory show that this virtuous cycle is a powerful driver of innovation and economic growth.[90]

Hal Varian of Google concluded, "It is now possible for everyone on the planet to have access to all the information humans have ever produced. The barriers to this utopian dream are not technological, but legal and economic. When we manage to solve these problems, we will be able to unlock vast pools of human potential that have hitherto been inaccessible. In the future this will be viewed as a turning point in human history, and economic advances generated by global access to all information will be recognized as the true value of the internet."[91]

[90] http://www.muninetworks.org/reports/community-based-broadband-solutions-benefits-competition-and-choice-community-development

[91] http://www.economist.com/blogs/freeexchange/2013/03/technology-1

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